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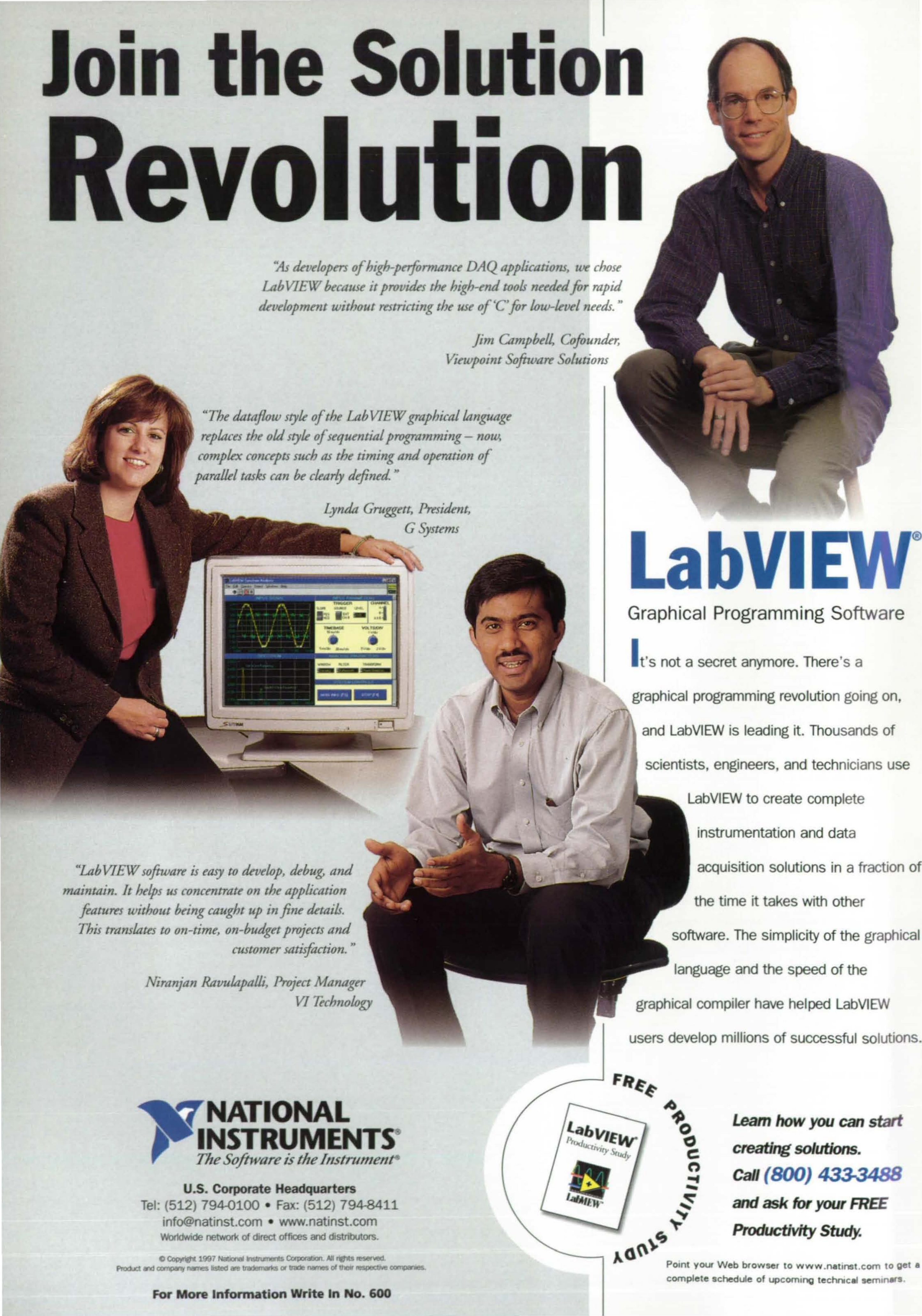
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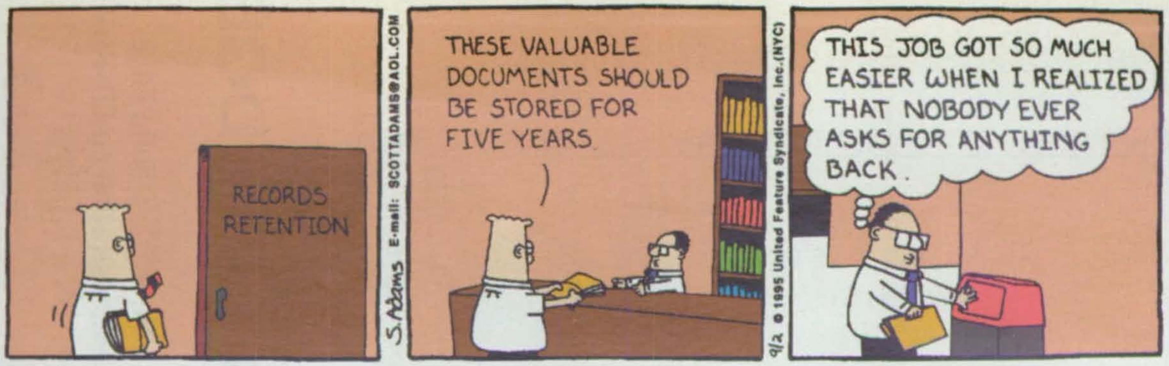


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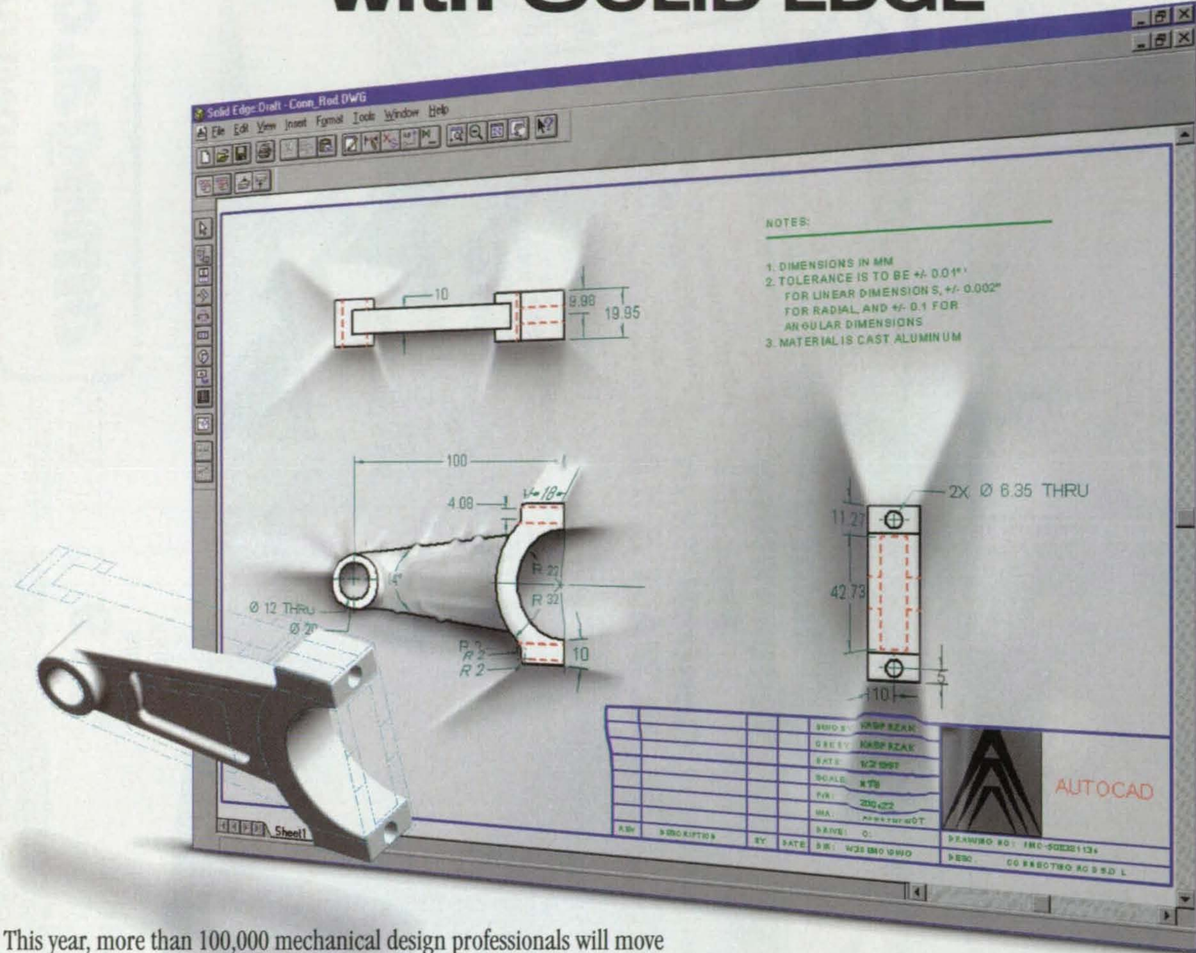


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[1] *Computer Aided Design Report*, Vol. 16, No. 6, June 1996

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TechniCom, Inc., Clifton, NJ, Mid-Range MCAD Benchmark Report, November 1996
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May 1997 • Vol.21 No.5

## Features

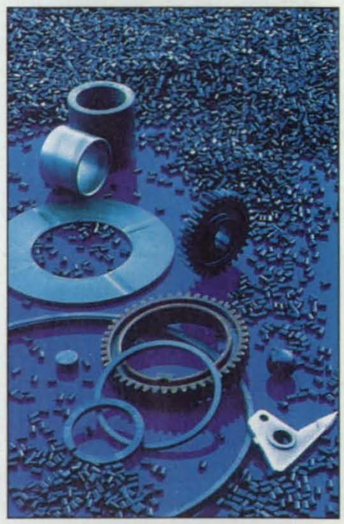


## Briefs



## Departments





*AURUM® thermoplastic polyimide from Mitsui Toatsu Chemicals, Purchase, NY, is an injection-moldable engineering plastic used in the automotive, aerospace, and industrial equipment industries. It is one of the Advanced Composites, Plastics and Metals highlighted in the Special Focus beginning on page 26.*

Photo courtesy of Mitsui Toatsu Chemicals

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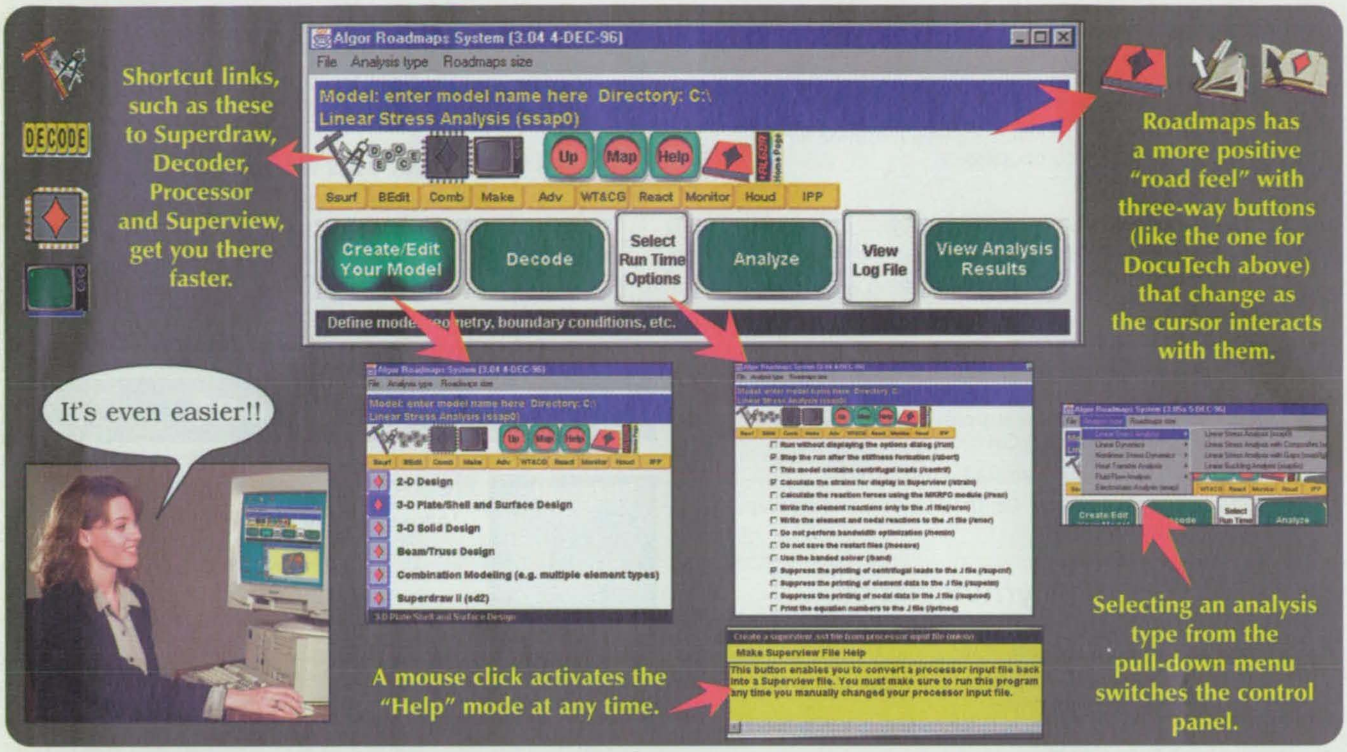


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# Contents *continued*



## Special Supplement


### Electronics Tech Briefs

Follows page 80 in selected editions only.

**On the cover:**

*More than 65,000 attendees and 3,000 exhibitors took part in National Manufacturing Week, held in March. Consisting of three industry shows – the National Design Engineering Show (NDES), the National Industrial Automation Show, and the National Plant Engineering & Management Show – the event marked the introduction of new products, including four series of gearmotors from Bison Gear and Engineering of Downers Grove, IL. A showcase of other new products introduced at the show begins on page 22.*

Photo courtesy of Bison Gear and Engineering




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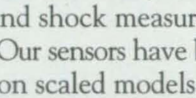

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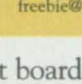

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*merle.mckenzie@ccmail.jpl.nasa.gov*

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## NASA Program Offices

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**For More Information Write In No. 577**

# Reader Forum

*Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.*

*In response to a letter by Jeffrey P. Kaylin in the January Reader Forum regarding the use of magnetic hoof protectors for horses, the Albert Roy Davis Research Laboratory in Green Cove Springs, FL has been researching biomagnetics since 1928, and has published its results. Mr. Kaylin may want to read them.*

John Forgette
forjet@softcom.net

*Reader Joseph Hunter inquired in the March Reader Forum about a source of image compression software that will run on PCs, based on fractal reduction of the images. Iterated Systems of Norcross, GA (770-840-0029) distributes a package called The Desktop Fractal Design System through Academic Press (AP). This is a quasi-tutorial system, but I'm sure that if he contacted Iterated Systems, they also would have more industrially oriented products. The AP office that handles the tutorial product is located in San Diego.*

Howard Mark, PhD
The Near Infrared Research Corp.
Suffern, NY

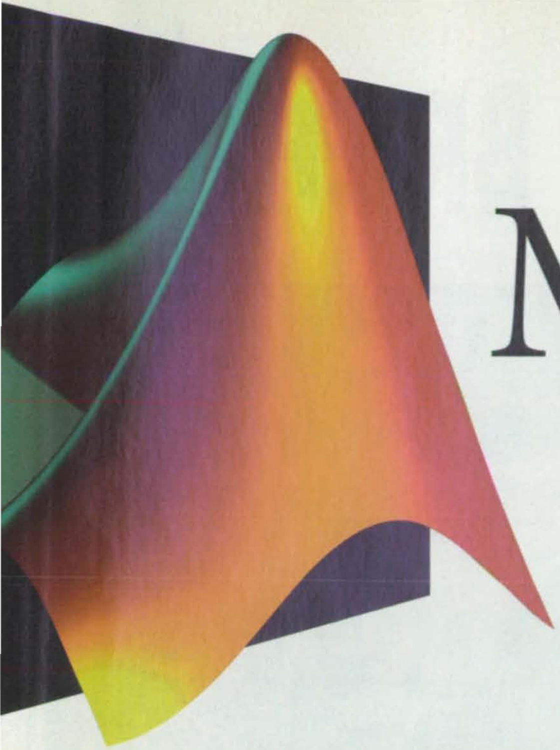
*I am looking for precision distance measuring equipment (laser, sound, etc.) with accuracy to 0.002". I would appreciate any suggestions on where to locate such equipment.*

Alan Lieberman
Techneglas
Columbus, OH

*In the January Reader Forum, a reader requested help in finding a source of graphite or other light material. I suggest Fibre Glast Developments Corp. of Brookville, OH (800-214-8571). I have used them for many years in my fiberglass projects. They offer fiberglass, epoxies, gel coats, and carbon fiber for purchase in small quantities, as well as videotapes, books, and classes for working in various media.*

Rick Markowski
Advanced Assembly Automation
Dayton, OH

**Send your letters to the Editor at:**
Reader Forum, *NASA Tech Briefs*, 317 Madison Ave., Ste. 1900, New York, NY 10017.
Fax: 212-986-7864; E-mail: ntb_edit@mindspring.com
Please include your name, company (if applicable), address, and phone number or e-mail address.



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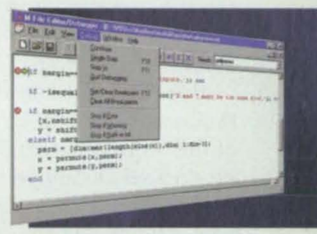

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*MATLAB lets you model complex data graphically. Here, lighting effects highlight topography data. Source: NOAA.*

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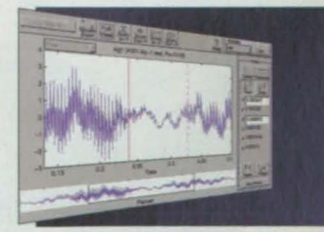

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**For More Information Write In No. 660**

# NASA NEWS BRIEFS

The 1996 *NASA Tech Briefs* Readers' Choice Awards for Product of the Year were presented recently at a reception during National Manufacturing Week in Chicago. The Gold Medal for Product of the Year was awarded to Knowledge Revolution of San Mateo, CA for its Working Model 3D™ virtual prototyping and design software. Silver Medal honors went to FieldWorks of Eden Prairie, MN for the Field WorkStation™ FW7600 portable computer, and the Bronze Medal award was presented to LeCroy, Chestnut Ridge, NY, for the LC334 and LC534 digital storage oscilloscopes.

Each month, *NASA Tech Briefs* highlights a Product of the Month, which features exceptional technical merit and practical value. Readers were asked in the December issue to vote for the one product among those highlighted during the year that represented the most significant new innovation for the engineering community. The product receiving the most votes was named the Gold Medal Product of the Year.

Also recognized at the awards ceremony were the following Product of the Year Finalists, all of which had received Product of the Month honors during 1996: Computervision's Electronic Production Definition software suite; Fluke Corp.'s ScopeMeter® B handheld test tool; SensorPulse Corp. for SensorPulse™ analog signal processors; Intergraph Corp. for Solid Edge™ assembly/modeling software; Matra Datavision, for the Euclid Quantum CAD/CAE/CAM/PDM software suite; Nomadics' plug-in modular instruments; Silicon Graphics for Onyx InfiniteReality™ visualization supercomputer; and Software Partners/32 for the SafetyPosit data backup service.

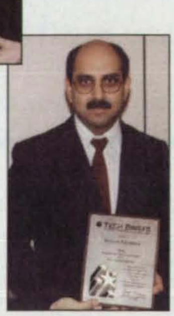
NASA Tech Briefs *Publisher Joseph Pramberger (left) and Chief Editor Linda Bell present the 1996 Readers' Choice Product of the Year Gold Medal Award to Dave Baszucki, President of Knowledge Revolution, for the Working Model 3D software.*

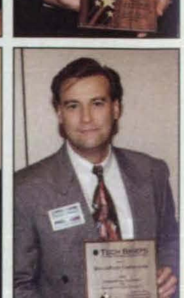
*The* NASA Tech Briefs *Readers' Choice medal winners (left to right): Vincent Dipas of FieldWorks, Silver Medal award; Dave Baszucki of Knowledge Revolution, Gold Medal winner; and Janet Hartley representing LeCroy, winners of the Bronze Medal.*

*The Gold Medal Team (left to right) – Knowledge Revolution's Steve Gottwalls, Greg Haywood, Dave Baszucki, and Ken Tokusei – with their award for 1996 Product of the Year.*

*Vincent Dipas (center) of FieldWorks accepts the Silver Medal award from* NASA Tech Briefs' *Joe Pramberger and Linda Bell.*

*Janet Hartley, representing LeCroy, was presented with the Bronze Medal award.*





*Product of the Year Finalist awards were presented to (clockwise from top): Shelley Miller and David Primrose of Intergraph Corp.; Matra Datavision's Bruce Boes; Kevin Roach of SensorPulse Corp.; Richard Mattson (left) and Henk Koppelmans from Fluke Corp.; and Ravi Chhabrice of Silicon Graphics.*

The Next Generation Internet (NGI) initiative could, by 2002, result in information flowing 1,000,000 times faster than today's home computer modems and 1,000 times faster than a standard T1 business computer line. NASA's Ames Research Center was named lead institution for NASA's $30 million portion of the three-year, $300 million federal project to develop the NGI. NASA has teamed with the National Science Foundation, the Defense Advanced Research Projects Agency, the Department of Energy, the National Institutes of Health, and the National Institute of Standards and Technology to conduct R&D that could interconnect core sites with high-speed lines late this year.

According to Christine Falsetti, NGI project manager at NASA Ames, the NGI initially will be a national network, "but we are looking for international partners to meet our global needs. Technical advances will spin off from NGI, and industry will put improvements into the old Internet to make it work better and faster." The project will include connecting computer networks of regional core organizations. For example, the federal government will hook up about 100 universities, research labs, and other institutions at 100 times the present speed. NASA has five sites – Ames, Goddard Space Flight Center, Langley Research Center, Lewis Research Center, and Jet Propulsion Laboratory – connected at a speed of 155 Mb that will soon be converted to 622 Mb.

Falsetti expects medical use of NGI to be significant. "You'll go to your local doctor, and he will be able to consult with specialists across the globe. That means you can get access to the best medical expertise in the world." She believes that the NGI will enable new Internet applications, such as viewing high-quality video programs on demand.

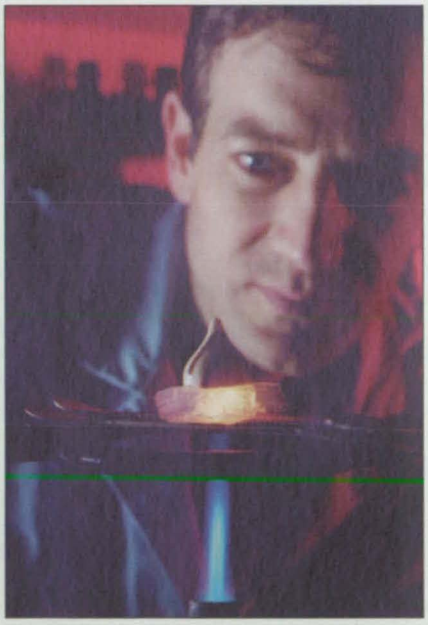
*For more information, contact John Bluck of NASA's Ames Research Center at 415-604-9000, or visit the Ames Public Affairs home page at: http://ccf.arc.nasa.gov/dx.*

The Computer Software Management and Information Center (COSMIC) at the University of Georgia has signed a three-year Space Act Agreement with NASA to distribute NASA's software technology to private industry. As a research division of the University of Georgia, COSMIC has worked with NASA for the past 31 years to transfer NASA software to the public.

"I think COSMIC is the first and, currently, the only technology transfer entity that operates independent of external financial support," explained Tim Peacock, COSMIC Director. COSMIC markets NASA programs that have significant technology and commercial potential. COSMIC checks each program's operation to ensure that it gives accurate results. It also supplies supporting documentation to help program users. The majority of COSMIC's software packages include full source code for limitless re-use of programs.

*For more information, contact Tim Peacock of COSMIC at 706-542-3265; e-mail: timp@cosmic.cosmic.uga.edu.*

You won't be able to see it, but NASA scientists may soon give household windows a new look – while saving energy and money. Researchers at NASA's Marshall Space Flight Center are collaborating with scientists at Lawrence Berkeley National Lab on an experiment in space with Aerogel, the lightest known solid material. Aerogel has only three times the density of air; a block the size of a human weighs less than one pound, yet is able to support the weight of a compact car. It has tremendous insulating capability, and when made on the ground, is hazy or smoky in appearance. If scientists are able to make the material transparent, a host of new products may result for insulating windows that will conserve energy and save money. A one-inch thick Aerogel window has the same insulation value as 15 panes of glass and trapped air, which means an equivalent conventional window would have to be 10 inches thick.



*NASA scientist Dr. David Noever watches as a half-inch of Aerogel insulation protects a chocolate candy from the heat of a blow torch.*

Last April, NASA produced 16 test samples of Aerogel aboard a Starfire Rocket in a sub-orbital flight. Dr. Laurent Sibille, a member of the three-man Marshall team, said samples produced in microgravity indicated a change in the microstructure of the material, compared to ground samples. The results were achieved after seven minutes of low gravity. Dr. David Noever said his Marshall team is preparing for the January 1998 launch of Space Shuttle Discovery, which will fly the experiment to test Aerogel with longer exposure to low gravity.

While no one knows why Aerogel made on the ground is smoky instead of clear, it is known that Aerogel is a good insulator because of the material's large internal surface area. Raymond Cronise, also of the Marshall team, explained that Aerogel "has so many sides and surfaces that if you could unfold a sugar-cube-sized portion, it could cover a basketball court."

*For more information, contact Steve Roy of Marshall Space Flight Center's Office of Media Services at 205-544-4159; e-mail: steve.roy@msfc.nasa.gov.*

NASA's Kennedy Space Center has begun offering free computer software to education institutions. The program follows last year's one-time computer system donation from the center, and complements an ongoing program that allows schools to claim surplus computer hardware.

"There is a continuous turnover of software at the space center and we regularly receive a wide range of DOS-based and Windows applications for our loan program," said program coordinator Doug Hendriksen. While the software inventory changes, the center usually has a selection of word processing, graphics, spreadsheets, database management, and specialized applications software for all educational levels. Also available, said Hendriksen, is a selection of networking and Macintosh software, as well as keyboards, mouses, cables, and other accessories.

*For more information, contact Doug Hendriksen of Kennedy Space Center at 407-867-2551.*

# NASA's Government Invention of the Year

***The NASA Government Invention of the Year for 1996 recently was awarded to Dr. Bruce Steinetz and Mr. Paul J. Sirocky (retired) of NASA's Lewis Research Center, Cleveland, OH, for their High-Temperature, Flexible Fiber Preform Seal.***

Inventors Bruce M. Steinetz (right) and Paul J. Sirocky hold samples of their high-temperature, flexible fiber preform seals, winner of the 1996 NASA Government Invention of the Year award. The simulation of an operating jet engine behind them suggests just one of the applications of the seals.

The inventors and their team at Lewis originally developed the high-temperature fiber preform seal for the National Aerospace Plane Project. What was needed was a seal that would operate at or above 2000 °F, as much as 1000 °F in excess of the operating condition of conventional graphite or metal seals. The seal structure had to follow and seal significant (≥3/8-in.) engine sidewall distortions. Other key requirements were that it exhibit low leakage to limit parasitic losses, remain flexible at temperature, resist hydrogen embrittlement and oxidation, and be fabricable using available materials. The inventors also had to develop unique test fixtures to assess leakage and durability performance under extreme (≥1500) temperatures.

The team made the seals by braiding emerging high-temperature ceramic and superalloy fibers into a flow-resistant, flexible structure. The seals' unique braiding geometries minimize leakage and resist scrubbing caused by relative thermal growth of adjoining panels. They can seal complex geometries, retain resilience after high-temperature cycling, and support structural loads.

Since being patented in 1992, the seals have been demonstrated as an enabling technology in several applications. For General Electric, these braided "rope seals" provided a combined seal and compliant mount to minimize thermal stresses in high-temperature nickel-aluminide turbine vanes. The company tested the vane/rope seal system in a full-scale Joint Turbine Advanced Gas Generator (JTAGG) engine demonstration, and over many cycles the vane showed none of the thermal cracking problems that beset the conventional brazing approach. The high-temperature vane/seal technology, combined with several others, contributed to meeting JTAGG Phase I program goals, which included a 20-percent reduction in specific fuel consumption and a 40-percent increase in power-to-weight ratio in a 4000-to-6000-horsepower turboshaft engine.

Pratt & Whitney is evaluating the invention as a replacement for sealing interfaces between large turning vanes and flow-path fairing elements in the F-119 engine for the F-22, the country's next-generation premier fighter aircraft. The potential for improved durability spurred the company to examine the hybrid version of the seal, consisting of a ceramic core and a superalloy sheath, which shows increased abrasion resistance.

Williams International is also evaluating the all-ceramic (ceramic sheath/core) version of the seal, using it to both seal and structurally support a high-temperature uncooled engine transition segment for an advanced demonstrator turbine engine. Temperatures in this application reach above 2000 °F, beyond the capabilities of any other seal.

Other than the engine industry, under a reimbursable Space Act Agreement, Lewis is working with a major U.S. producer of industrial gases to adapt the seal technology to proprietary high-temperature gas systems. In this application, the seal must prevent parasitic leakage and allow tubes to expand without excessive thermal stresses. Feasibility tests done by the partners have demonstrated that the seals operate successfully at temperatures above 1500 °F, meeting all of the performance criteria.

The inventors have been contacted by several companies interested in using the invention to seal thermal-protection system gaps on next-generation spacecraft (X-33) and as replacements for gaskets in turbocharger flanges. Other commercial applications might include furnace doors, emission control devices, energy conversion systems, combustor liners, and heat exchangers and recuperators that recover waste heat that would otherwise go out the flue stack. As industries adopt cleaner processes, combustion systems will require higher-temperature seals. Chemically active gases require seals such as these, made of chemically inert materials. Additionally, industrial and aerospace systems are going to higher temperatures to increase cycle performance, reducing fuel burn and emissions. As these trends fully develop, markets for these high-temperature seals will evolve.

Steinetz, a Senior Research Engineer at Lewis, leads NASA's engine seal development team that finds seal solutions for aerospace applications, including the fiber preform seals and high-temperature turbine shaft seals. Sirocky was a Senior Project Engineer at Lewis until his retirement. Researchers Mike Adams and Lawrence Kren helped perform laboratory feasibility tests qualifying the fiber seals for subsequent engine and industrial system tests.

*For more information, contact Dr. Bruce Steinetz at (216) 433-3302; fax (216) 977-7051.*

# National Design Engineering Show New Product Showcase

*The following products were introduced at the National Design Engineering Show.*

Mitsubishi Electronics America, Sunnyvale, CA, has introduced the 3Dpro™/2mp **chipset**, which provides the features of 3D workstations on the Windows NT platform. It delivers 32-bit color, double-buffered 3D graphics at up to 1280 × 1024 resolution, and consists of three components: a rendering processor based on REALimage™ technology from Evans & Sutherland; 3D-RAM as the frame buffer, and CDRAM as local texture memory. REALimage integrates 3D pipeline processes of setup, scanning, shading, and hardware texturing in one chip, and offers support for MIP-mapped texturing, anti-aliasing, and bilinear and trilinear MIP mapping. The chipset supports Windows NT/95, as well as most 3D software applications.

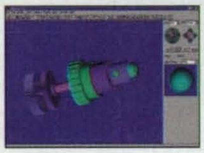
**For More Information Write In No. 745**

**Luminescence detectors** from Balluff, Florence, KY, read invisible ultraviolet markings to eliminate the need for visible marks on products. The sensors can be used to verify critical processes, provide presence and position sensing, enhance quality control, and perform product identification. They read UV markings on wood, metal, plastic, ceramic, paper, or textiles with chalk, ink, wax, or powders. They also read UV markers mixed into glues, sealants, solvents, grease, oils, and fluids. Operating distances range from 5 to 80 mm and spot diameters from 3 to 25 mm. The detectors emit UV light on 350 nm wavelength converted to visible light upon striking a luminescent object or mark.

**For More Information Write In No. 746**

Bison Gear and Engineering, Downers Grove, IL, has introduced four **gearmotor** series: the Series 175 high-torque units; the Series 650 parallel shaft gearmotors; and single-reduction and double reduction series right-angle gearmotors. The 175 parallel shaft gearmotors for tight space applications feature torque ratings to 175 inch-pounds, gear ratios from 5:1 to 1369:1, and 1/10 or 1/20 HP AC motors, or 1/8 or 1/20 HP DC motors. The Series 650 gearmotors deliver torques to 720 inch-pounds in two-, three-, and four-stage versions. Gear ratios range from 11:1 to 2206:1 and speeds range from 0.7 to 160 RPM. Right-angle units in single and double reduction feature hollow hardened steel output shafts and integral AC or DC motors.

**For More Information Write In No. 747**



Solid Concepts, Valencia, CA, has introduced SolidView Version 2.1 3D **mechanical design visualization software** for communicating 3D design information across dissimilar modeling systems. The new version allows importing of VRML data, allowing engineers with access to a Windows-compatible PC to view designs, measure, and add annotations. The program uses standard stereolithography files generated from CAD systems to view 3D designs, regardless of their source. Users can send a free viewer with their designs and an IGES import option allows users to view and measure IGES surface data. Requirements are a 486 or Pentium PC with 8 MB of RAM and Windows 3.1, 95, or NT.

**For More Information Write In No. 749**

Kollmorgen Motion Technologies Group, Radford, VA, offers the BMS-1210 Series direct-drive **brushless servomotor**, which utilizes a Hall sensor ring assembly for commutation and eight rare earth permanent magnets. The motor produces a peak torque of 228 oz-in and a continuous torque rating of 70.14 oz-in at stall. Designed for 28-volt DC operation, windings also are available to accommodate other voltages. The servomotor is suitable for applications requiring a frameless, high-torque unit in a compact package.

**For More Information Write In No. 750**

Fuzzy Logic Design for G interactive **design software** from National Instruments, Austin, TX, can build virtual instruments for use with BridgeVIEW™ and LabVIEW® application software. System developers can run fuzzy control systems for process control, creating virtual instrumentation systems for pattern recognition or diagnosis. The program also is compatible with PID control and statistical process control toolkits. It consists of interactive software for designing control systems, as well as virtual instruments for running the user-designed fuzzy control systems. The designs are suited for non-linear control systems in industrial automation and real-time control.

**For More Information Write In No. 751**

Intergraph Software Solutions, Huntsville, AL, has introduced Imagineer Technical™ 2.0 **2D CAD software** that features 2D kinematic animation, enabling modeling and visualization of mechanisms. The new version supports user-definable dimension axes, as well as stacked and string dimensions. An embedded symbol browser based on Microsoft Internet Explorer 3.0 allows users access to data on the Web. Users can drag and drop symbols into drawings and publish information on the Web as ActiveX documents or ActiveCGM™. MicroStation® or AutoCAD drawings can be imported; data also can be sent to Solid Edge™, AutoCAD Mechanical Desktop, SolidWorks, or other mechanical design programs. It runs on Windows 95 or NT and requires a 486/66-MHz system with 16 MB RAM.

**For More Information Write In No. 752**

Parker Hannifin Corp.'s Brass Products Div., Otsego, MI, has introduced the Presto® **encapsulated cartridge** for installation in single soft metal or thermoplastic cavities without special tooling. A positive-stop shoulder prevents the cartridge from being pushed too far into the cavity. The cartridges are engineered for pressure applications from 27 inch vacuum to 300 psi with a temperature range from -40°C to 93°C. They are available in sizes from 1/8" through 1/2" O.D. and accept nylon, polyethylene, polyurethane, or soft metal tubing. An encapsulated Nitrile O-ring is standard for general-purpose sealing.

**For More Information Write In No. 753**

The COMPACT™ Series 1 **pendant arm** from Hoffman, Anoka, MN, allows horizontal and vertical positioning of small operator interface enclosures, enabling small interface devices to be positioned by machine tool operators for the best viewing angle. Operator interface enclosures up to 40 pounds can be adjusted vertically by the operator. Made of aluminum, the arm attaches to a machine or wall, and adjusts for individual needs. An enclosure mounting plate can be rotated, tilted, and locked into position, while a vertical axis braking mechanism prevents freefall motion when locked. The arm is available in lengths of 500 and 600 mm.

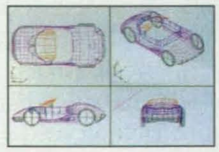
**For More Information Write In No. 754**

Tecnomatix Technologies, Novi, MI, has introduced PART™ **machining software,** which generates the machining process plan and associated toolpaths required to machine a part. Using solid models from most CAD systems, the software automatically recognizes manufacturing features and can recommend set-ups, select cutting tools and machines, optimize machining operations, and produce NC toolpaths and reports. Machining methods are stored in an Oracle database, allowing users to manually and interactively modify, adjust, and influence the process plan. Reports generated include a list of operations, required cutting tools, fixtures, set-up sketches, and machine time and cost. The program runs on Silicon Graphics and Hewlett-Packard UNIX workstations.

**For More Information Write In No. 755**

PORON® **urethane foam materials** from Rogers Corp. High Performance Elastomers Div., East Woodstock, CT, were designed for gasketing, sealing, and vibration-absorption applications. The materials offer flame-retardance, low outgassing, and low fogging properties, and meet UL 94 HBF requirements. They offer compression set resistance, extended life, and a Total Mass Loss of less than 1% for most densities when tested for 24 hours at 125°C, eliminating fogging effect. The foams are used in electronics applications such as monitor and display seals, shock-absorbing pads, and vibration-isolation cushions.

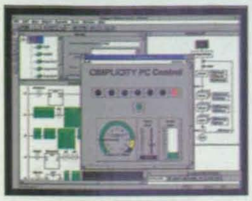
**For More Information Write In No. 756**



HighRES, La Jolla, CA, has announced HighRES 4.0 for Windows, a PC-based **reverse engineering software** package for Windows NT 4.0 and 95. The turnkey toolset includes HighRES Studio, CADKEY®, FastSURF®, and an Immersion Microscribe 3DX® digitizer. The program captures the surface of a physical 3D object or prototype and transfers the data into a CAD environment for creation of an identical 3D digital model. Captured data can be used for 3D wireframe and NURB surface creation, rapid prototyping, moldmaking, and CNC and CMM analysis. The model creation process can begin during or after the digitizing process. Users can observe the creation of data from virtually any viewpoint during the digitizing process.

**For More Information Write In No. 757**

# National Design Engineering Show New Product Showcase



CIMPLICITY® PC Control **computer interface control software** from GE Fanuc Automation North America, Charlottesville, VA, was designed for industrial automation operations in the semiconductor, material handling, automotive, and process industries that use PC-based human-machine interfaces (HMIs). Based on Windows 32-bit architecture, users can link the program to their applications or to Microsoft products such as Excel™ and Visual Basic®. The software incorporates a runtime logic engine for Windows NT and program editors that run on Windows 95 or NT.

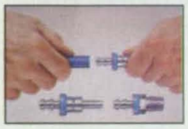
**For More Information Write In No. 758**

Hyperkernel™ 4.0 **software development program** from Nematron Corp., Ann Arbor, MI, enables software developers to implement hard real-time systems applications that execute cooperatively with Windows NT and 3.51. The package includes one seat development system, one runtime license, test software for benchmarking system performance, and documentation. It enables devices such as robots, process controllers, and machine control systems to be configured as application servers on any standard network system. The software features high-speed timers, memory management, file system services, task scheduling and prioritization, and interrupt handlers.

**For More Information Write In No. 759**

Warner Electric Div. Dana Corp., South Beloit, IL, has introduced the TD and TDC Series **brushless DC servo systems**, which are available in 8-amp and 16-amp peak output current rating versions. The TD Series system includes an amplifier and power supply; the TDC Series includes the amplifier, power supply, and a positioning controller. The systems were designed for applications requiring pre-engineered and pre-packaged DC servo systems.

**For More Information Write In No. 760**



Swagelok Co., Solon, OH, has announced the Push-On **hose**, which requires no special tooling to assemble and can handle a range of system fluids. The hose is cut to the desired length and is pushed onto the end connection. Proper assembly is ensured when the hose seats within the blue finishing cap on the shoulder of the end connection. The reusable ends are available in brass and 316 stainless steel in sizes ranging from 1/4" to 3/4" and from 6 mm to 18 mm. Four styles are available: Swagelok Tube Adapter, Male NPT, Male BSP/ISO Tapered, and Hose Union. The hose features a Buna-N cover that is resistant to oils, weather, and abrasion. Hose inside diameters are 1/4", 3/8", 1/2", and 3/4"; temperature ratings are -40° to 95°C.

**For More Information Write In No. 761**

Dynapro Technologies, New Westminster, BC, Canada, offers the Ergo Touch 4000 PC-based **flat panel computer** that incorporates Near Field Imaging (NFI) touch technology. The computer features clear optics and a customizable TouchSurround™, which enables OEMs to tailor the touch input area to reflect a user's specific keys, buttons, and logos. It features up to 200 MHz Pentium technology, is NEMA 4X rated on the front panel, and is available in display sizes of 10.4", 12.1", 13.8", and 17.7".

**For More Information Write In No. 762**

The PEM® Type FH4™ self-clinching flush-head **studs** from Penn Engineering & Manufacturing Corp., Danboro, PA, provides strong threads in stainless steel sheets as thin as 0.040". The studs create a flush-head assembly and lock with high torque-out and pushout resistances. They are made from 400 Series stainless steel and were designed for use in stainless steel sheets with a hardness of HRB 92 or less. The studs are installed by placing them in punched or drilled holes in the sheet and squeezing them into place with a standard press. They are available in thread sizes of #4-40, #6-32, #8-32, and #10-32, and in millimeter sizes of M3, M4, and M5. Lengths range from 0.250 to 1.5" and 6 mm to 35 mm.

**For More Information Write In No. 763**

Raytek Corp., Santa Cruz, CA, has introduced the Raynger 3I LRSCL2 **infrared thermometer** with both scope and laser sighting combined in one unit. Both aiming options can be used together to pinpoint the center of a target with a laser spot and instantly read the temperature from distances to 110 feet. Areas as small as 6" can be measured from up to 60 feet away. The thermometer is used to check heating and cooling efficiency of running equipment; monitor electrical systems, motors, or bearings; or spot-check temperatures during manufacturing processes. It has a temperature range of -30°C to 1200°C and operates on four AA alkaline batteries or an external 6-9 VDC, 200 mA power source. It is held in one hand and features a locking trigger, audible alarms, and Recall Last Reading.

**For More Information Write In No. 769**

The VAMP-Pan Vista 17.7" color **flat panel display** from Computer Dynamics, Greenville, SC, features 1024 × 768 resolution and offers the same viewing area as a 21" CRT. Display sizes of 15.1" and 13.8" are available, as well as an optional guided acoustic wave or resistive touchscreen. The unit features a display of 512 colors, 150 nt brightness, and a 25:1 contrast ratio. It accepts synch-on-green, composite, and other custom analog signals. System dimensions for the open-frame unit are 18.7 × 14.3 × 3.5". Enclosures and swing-arm mounts for wall, ceiling, or machine mounting are available. The unit consumes 30 watts and is rated for operation in 0°C to 40°C.

**For More Information Write In No. 770**

Sixnet, a Digitronics Co., Clifton Park, NY, has introduced Sixlog **remote data-logging software** for Windows-based systems. It provides data-logging in remote sites in Windows-compatible files that can be transferred back to a host Windows system for playback and analysis. The program includes a Windows setup utility that allows users to drag I/O tags definitions from popular Windows applications. Up to 1 MB of data can be stored in battery-backed memory; data can be stored as fast as 10 milliseconds. Files can be retrieved and stored in Windows 3.1, 95, and NT systems.

**For More Information Write In No. 771**

VIA Development Corp., Marion, IN, offers VIA Electrical Controls Design Software 5.0, an AutoCAD-based **controls design software** that links schematics, multiple reports, panel drawings, and wire labels. Compatible with Windows 95 and NT, the software includes a Visual Device Insertion feature that provides a graphical device menu, and a Global Attribute Editor that permits instantaneous editing for drawing sets. The Panel Builder module enables users to highlight components in the device list, and drag and drop them to create a panel drawing.

**For More Information Write In No. 772**

The Airstroke® 2M2A Microactuator from Firestone Industrial Products, Carmel, IN, is a pneumatic bellows-type **air spring** with a maximum diameter of 2.2" and a height of 1.2". It can utilize pressures from zero to 100 psi and is suitable for small-space applications. The air spring can deliver more than one inch of stroke and provides flexible actuation. They can be used in place of air or hydraulic cylinders and can lift 200 pounds at 100 psi.

**For More Information Write In No. 748**

The IM481H **hybrid microstepping driver** from Intelligent Motion Systems, Marlborough, CT, measures 1.1 × 2.7 × 0.17" and features short-circuit and thermal protection, adjustable automatic current reduction, and single supply at full step and fault outputs. The 96-watt bipolar drive accepts an input voltage of 12 to 48 volts and incorporates ASIC technology to reduce heating and allow low inductance stepper motors to be used. The driver has 14 built-in microstep resolutions from 400 to 51,200 steps/revolution in binary and decimal that can be changed without resetting the driver.

**For More Information Write In No. 776**

*continued on page 91*

# Commercialization Opportunities

### Lightweight, Thermally Insulating Structural Panels

Structural panels have been developed with superior thermal-insulation properties. Compared with earlier panels, these have about 50 percent less mass density and 30 percent less thermal conductivity.
(See page 32.)

### Successive-Approximation ADCs With Capacitive Coupling

Prototypes of analog-to-digital converter (ADC) circuits have been developed that will be incorporated into advanced video cameras. These ADCs contribute to miniaturization and offer other features.
(See page 46.)

### Time-Interval Unit Achieves Picosecond Resolution

This unit incorporates GaAs or other high-speed, low-jitter semiconductor circuitry, which increases accuracy.
(See page 50.)

### High-Pressure, High-Temperature Oxygen DTA/TGA System

A laboratory system was developed for performing differential thermal analysis and thermogravimetric analysis of materials at high temperatures in high-pressure oxygen. The system can be used to identify materials that are safer and less vulnerable to oxygen. Other gases may be used instead of oxygen.
(See page 60.)

### Sputter Texturing to Prepare Surfaces for Bonding

This process can be used to texture complexly shaped surfaces to increase bonding strength between parts; e.g., metal fixtures to composites. It can also texture prosthetic devices; e.g., hip implants to promote bonding of tissue to the implant after the surgery.
(See page 81.)

### Fiducial Grids for High-Resolution Beam Lithography

A fiducial grid and new method can determine the position of a beam to within a few nanometers. Such precision is critical for making high-resolution masks with patterns accurate enough for x-ray lithography of state-of-the-art integrated circuits.
(See page 82.)

### Instrument Measures Populations of Microbes in Water

An "on-line microbial analyzer" measures population densities of several species of microbes in flowing water. The instrument was conceived for monitoring harmful microbes in hydroponic nutrient solutions. Modified versions could be used for monitoring drinking water and treated wastewater.
(See page 89.)

# Special Focus: Advanced Composites, Plastics & Metals

## Microwave-Induced Combustion Synthesis of Ceramic/Metal Composites

### Heating proceeds from the inside out rather than from the outside in.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Microwave-induced combustion synthesis has shown promise as a technique for making improved ceramics and ceramic/metal composites. Combustion synthesis is also called self-propagating high-temperature synthesis (SHS) because it involves exothermic reactions that, once started, sustain themselves and propagate through the mixture that is the precursor of the material to be synthesized. SHS offers an attractive, energy-efficient approach to the synthesis of high-temperature composite materials and metastable phases. Microwave-induced combustion synthesis provides advantages over older techniques of SHS, as explained below.

Heretofore in SHS, it has been common practice to ignite the exothermic reactions at the surfaces of the samples of precursor mixtures by use of thermal radiation. In a given case, the thermal radiation can be delivered via a laser beam or from a heating coil placed close to the surface of the sample. Alternatively, the entire sample can be heated to the ignition temperature in an isothermal furnace. The common feature of these ignition techniques is that they produce gradients of temperature in the samples; the surfaces being always hotter than the center.

Microwave-induced combustion synthesis is suitable for cases in which the precursor materials have little or no electrical conductivity. The microwaves penetrate a sample of such a material, delivering heat to the interior. The interior heating results in a temperature gradient that, qualitatively, is the reverse of the gradient produced by thermal radiation. Thus, the combustion front propagates radially outward from the center of the sample. The microstructure of the product material can be completely different from that of the product material obtained in SHS induced by exterior heating. The interior heating in microwave-induced combustion synthesis can also lead to a more complete conversion of reactants from the precursor mixture.

An experimental study was conducted to demonstrate microwave-induced combustion synthesis and to compare it with conventional SHS, using the model reaction $3TiO_2 + 3C + (4 + x)Al \rightarrow 3TiC + 2Al_2O_3 + xAl$. In some experiments, the precursor material contained no excess aluminum ($x = 0$); in others, there was excess aluminum ($x = 4$). (In a production scenario, one would incorporate excess aluminum if one desired to achieve a denser composite product by allowing the molten aluminum generated in the exothermic reaction to infiltrate the pores of the ceramic matrix of the product. The ductile aluminum offers the potential for toughening of the otherwise brittle composite material.)

In the experiments, various samples were subjected to slow and fast heating by external and microwave techniques, and some of the samples were uniaxially pressed at levels from 200 to 1,400 psi (1.4 to 9.7 MPa). In all the cases of slow heating, the reactions were incomplete; that is, the precursor materials were not converted completely to the composite product. For $x = 4$, solid $Al_2O_3$ whiskers were observed in the microwave-heated samples, whereas hollow $Al_2O_3$ whiskers with bulbous heads were observed in the conventionally heated samples (see figure). The $x = 0$ samples processed with fast and slow microwave heating reached higher densities than did the conventionally heated samples.

*This work was done by Martin B. Barmatz and Tzu-Yuan Yiin of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 30*** *on the TSP Request Card.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

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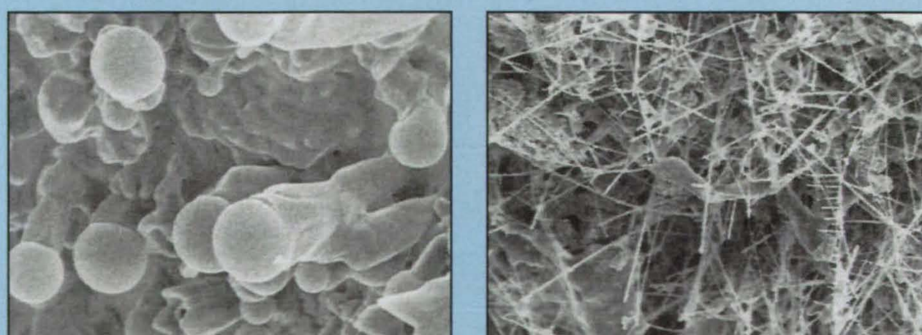
*Technology Transfer*
*California Institute of Technology*
*Mail Code 315 - 6*
*Pasadena, CA 91125*
*(818) 395-3288*

*Refer to NPO-19637, volume and number of this* NASA Tech Briefs *issue, and the page number.*




These **Scanning Electron Micrographs** of uniaxially pressed samples show different whisker microstructures, suggesting different formation mechanisms.

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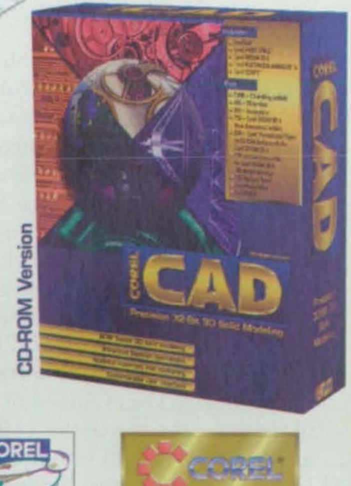


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# Advanced Thermomechanical Fatigue (TMF) Testing of Composites

## Degradation of measured elastic properties yields insight into the accumulation of TMF damage.

*Lewis Research Center, Cleveland, Ohio*

An advanced method for the thermomechanical testing of composite materials can be implemented in conjunction with any conventional or unconventional load-controlled cyclic thermomechanical fatigue (TMF) test (see Figure 1). The method involves the incorporation, into each collected TMF cycle, of measurements of the coefficient of thermal expansion (CTE) and of the isothermal static modulus of elasticity ($E$). Thus, CTE and $E$ are determined as functions of the cycle number. The evolution of the values of these parameters as the TMF test progresses yields insight into the accumulation of damage within the specimen.

The measurements of CTE and $E$ are automated. The basic TMF test conditions are altered only slightly. Figure 2 illustrates the method as applied during a typical TMF test with conventional in-phase cycles in which the temperature is cycled between lower and upper limits of $T_1$ and $T_2$, respectively, while an applied tensile load is cycled from zero to a specified maximum, in phase with temperature.

After each TMF cycle designated for data collection, the specimen is subjected to a thermal cycle identical to that of the TMF test, but the load is kept at zero. This thermal cycle is represented by the horizontal line from $T_1$ to $T_2$. The thermal expansion of the specimen is measured during this thermal cycle by use of a high-temperature extensometer, yielding data on the thermal strain response, by which CTE is calculated.

When the temperature reaches $T_2$, it is held there for a short time, during which $E$ is measured by applying a small load and measuring the strain; this measurement is indicated by the line marked

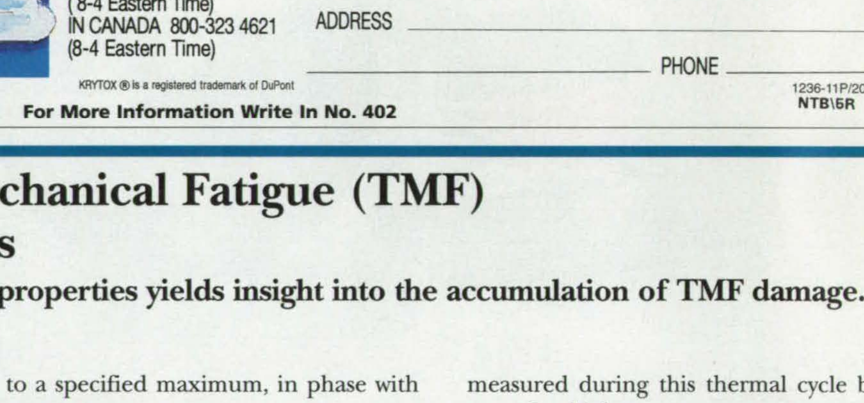



Figure 1. These **Thermomechanical Fatigue Cycles** are commonly used to test specimens of composite materials under relatively simple controlled conditions.

"$E_2$." At the end of the thermal cycle, the temperature returns to $T_1$ and is again stabilized for a short time while a similar measurement of $E$ is performed, as indicated by the line marked "$E_1$." Then the next full TMF cycle begins. The load applied to measure $E$ should be small enough so as not to introduce additional damage. For further information, see the following article: "An Advanced Test Technique to Quantify Thermomechanical Fatigue Damage Accumulation in Composite Materials," *Journal of Composites Technology and Research*, Vol. 16, No. 4, October 1994, pp. 323 – 328.

*This work was done by Michael G. Castelli of Sverdrup Technology, Inc., for* **Lewis Research Center**. *No further documentation is available.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Rd., Cleveland, OH 44135. Refer to LEW-16003.*

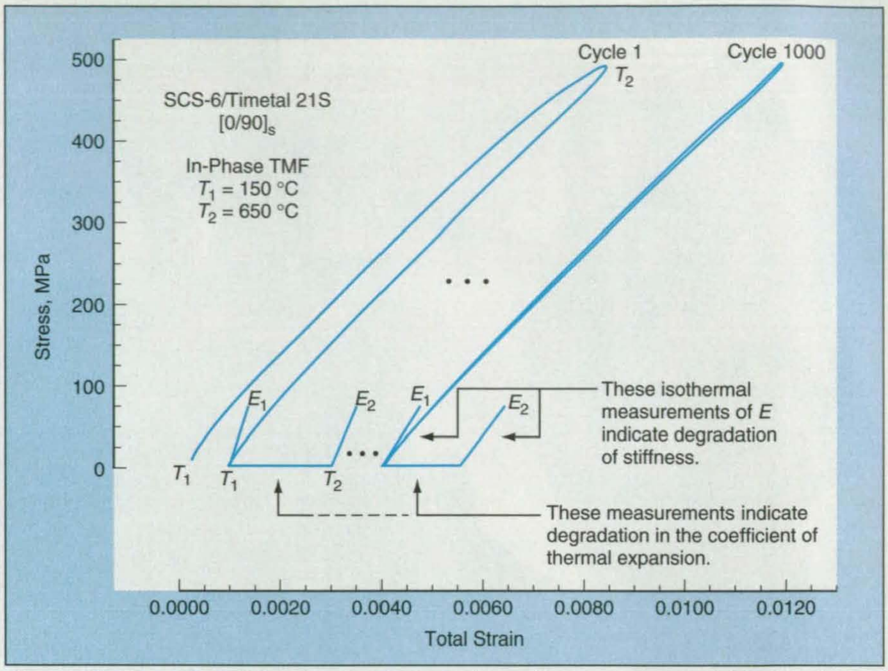



Figure 2. The **First and 1,000th Cycles of a TMF Test,** with ancillary zero-stress thermal and isothermal tensile cycles show degradation in the $E$ and CTE of a specimen of a titanium-matrix composite material.

# Increasing Cryogenic Fracture Toughness of Alloy 2195

## A modified aging heat treatment produces a better distribution of strengthening precipitates.

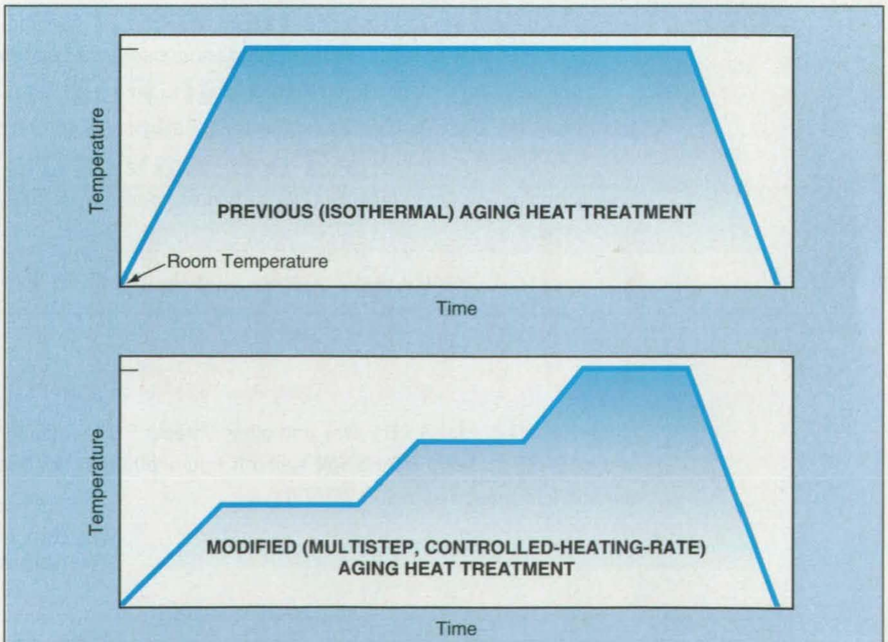
*Marshall Space Flight Center, Alabama*

A modified aging heat treatment for alloy 2195 has been found to yield greater cryogenic fracture toughness than does the previous aging heat treatment. Alloy 2195 is a strong, lightweight alloy of aluminum with copper, lithium, and small amounts of other metals. Increasing the cryogenic fracture toughness of this alloy could enhance its utility in tanks for holding cryogenic fluids.

Alloy 2195 is commercially available in the form of rolled plates. A rolled plate as supplied by the manufacturer is solution-heat-treated, then stretched by several percent at ambient temperature prior to aging heat treatment. The figure illustrates the differences between the previous and modified aging heat treatments. The previous aging heat treatment is an isothermal one, in which the plate is typically heated for 14 to 18 hours at 300 °F (149 °C).

The disadvantage of the isothermal aging heat treatment is that it does not result in a repeatable and optimum distribution of strengthening precipitates in the alloy microstructure. The precipitates occur preferentially along grain or subgrain boundaries and are distributed nonuniformly throughout the matrix. The results are that fracture toughness is less than it could be with a more nearly uniform distribution, and there are differences among the mechanical properties of plates made from different ingots of the same nominal chemical composition.

The modified aging heat treatment is a multistep, controlled-heating rate process. In one version of this treatment, the temperature of a plate is held at 260 °F (127 °C) for 10 hours, increased at a rate of 1 °F/h (5/9 °C/h) to 275 °F (135 °C), held at 275




The **Multistep, Controlled-Heating-Rate** aging heat treatment produces a more favorable distribution of strengthening precipitates, resulting in an increase in cryogenic fracture toughness.

°F for 20 hours, increased at a rate of 1 °F/h to 290 °F (143 °C), then held at 290 °F for 25 hours. Another version of this treatment involves the same heating rate and holding temperatures but different holding times. In comparison with the isothermal aging heat treatment, this heat treatment reduces the concentration of precipitates along the grain boundaries and provides an increased and more nearly uniform concentration of precipitates in the matrix. The net results are increased cryogenic fracture toughness, smaller ingot-to-ingot differences in mechanical properties, greater tolerance of ingot-to-ingot differences in chemical composition, and greater tolerance of variations in prior thermomechanical processing.

*This work was done by Tina W. Malone and William P. Stanton of* **Marshall Space Flight Center** *and Po-Shou Chen and A. K. Kuruvilla of IIT Research Institute. For further information,* ***write in 12*** *on the TSP Request Card.*

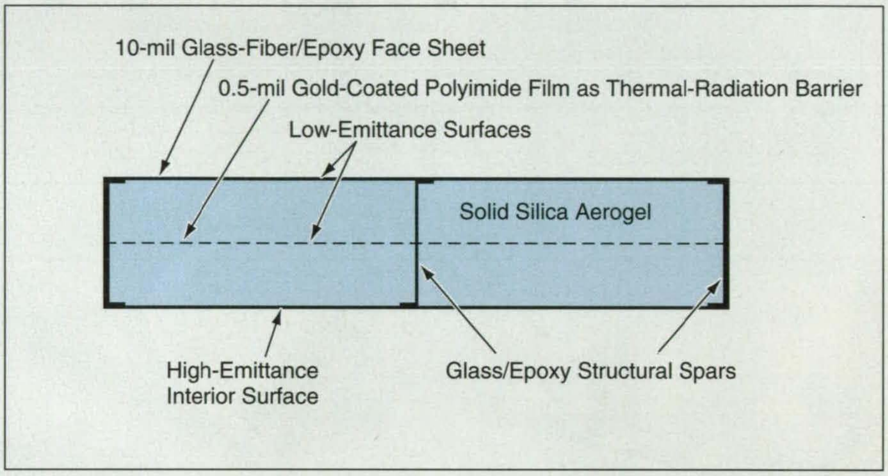
*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26359.*

# Lightweight, Thermally Insulating Structural Panels

## Aerogels and radiation-control films reduce heat transfer to unprecedented low levels.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Lightweight composite-material structural panels with superior thermal-insulation properties have been developed. These panels feature a sheet-and-spar construction with column (hollow-core) volumes filled with low-density solid silica aerogel (see figure). In comparison with the previous state-of-the-art panels comprising honeycomb cores filled with opacified silica aerogel powder, the present panels have about 50 percent less mass density and 30 percent less thermal conductivity. These panels could be particularly useful as integrated insulating and structural members in high-altitude aircraft, spacecraft, vacuum instruments, and low-pressure-processing equipment.




**Spaces in Columns** formed by spars and sheets are filled with a low-density, high-thermal-resistivity solid silica aerogel. Gold films at the outer surfaces, midplane, and inner surface reduce the radiative transfer of heat.

The spars and sheets are made of glass-fiber-reinforced epoxy. The silica aerogel filling has a mass of 1.25 lb/ft$^3$ (20 mg/cm$^3$), is hydrophobic, and exhibits high resistance to mechanical shock. The spatially averaged mass density of an experimental 1-in. (2.54-cm)-thick panel, including the sheets, spars, and insulation, was found to be 4.5 lb/ft$^3$ (72 mg/cm$^3$). Inasmuch as most of the mass of a panel comes from the glass-fiber/epoxy face sheets, a thicker panel would have less overall mass density.

The effective thermal conductivity of the experimental panel was found to be 0.033 W/(m·K) at a temperature of 24 °C. By pumping down to a vacuum with a residual pressure of $10^{-3}$ torr ($\approx 10^{-1}$ Pa), the effective thermal conductivity at 25 °C was made to decrease to only 0.0113 W/(m·K) (see table).

Convective heat transfer in a panel of this type is suppressed by the solid aerogel, the interstitial spacing of the lattice structure of which is orders of magnitude smaller than the mean free path of an air molecule at low atmospheric pressure. Conductive heat transfer is minimized by choosing a glass-fiber/epoxy composite with a low thermal conductivity and by minimizing the cross-sectional areas of spars and sheets. Radiative heat transfer is minimized by placing a low-emissivity film of gold-coated polyimide films on the outer surfaces of face sheets and at the midplane of the panel.

*This work was done by Gregory S. Hickey, David F. Braun, Peter Tsou, David K. Brown, William H. Mateer II, and Willis W. Han of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 14*** *on the TSP Request Card.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

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*Pasadena, CA 91125*
*(818) 395-3288*

*Refer to NPO-19504, volume and number of this* NASA Tech Briefs *issue, and the page number.*

| Condition | Temperature (°C) | Thermal Conductivity (W/m-K) |
|---|---|---|
| 1 atm | 25 | 0.0333 |
| 10 torr $CO_2$ | – 79 | 0.0089 |
| 10 torr $CO_2$ | – 27 | 0.0126 |
| 10 torr $CO_2$ | 25 | 0.0163 |
| $1.2 \times 10^{-3}$ torr Nitrogen | – 78 | 0.0049 |
| $1.2 \times 10^{-3}$ torr Nitrogen | – 26 | 0.0074 |
| $0.4 \times 10^{-3}$ torr Nitrogen | 25 | 0.0113 |

Additional **Thermal Conductivity Data** for the structure as a function of pressure and temperature are shown.

# Protective Coatings for Gamma Titanium Aluminides

**These coatings could be used to make lightweight components for turbine engines.**

*Lewis Research Center, Cleveland, Ohio*

Coating alloys of general composition Ti/Al/X (where X denotes Cr, Fe, or another suitable metal) have been developed recently to protect gamma titanium aluminide ($\gamma$-TiAl)-based alloys. At half the density of superalloys, $\gamma$-TiAl-based alloys are promising candidate materials for use at temperatures between 600 and 850 °C in turbine engines. Replacement of superalloys by $\gamma$-TiAl-based alloys would increase thrust-to-weight ratios in the engines and reduce the costs of operating them. However, protective coatings are needed because bare $\gamma$-TiAl-based alloys do not resist oxidation adequately and are potentially susceptible to embrittlement by oxygen and nitrogen; this is especially true at temperatures above 750 to 850 °C.

Aluminizing treatments, conventional MCrAlY (M = Ni or Fe) coating alloys, and ceramic coatings for $\gamma$-TiAl-based alloys have not proven successful because of poor mechanical properties, mismatch of thermal expansion coefficients, or chemical incompatibility. Promising coating alloys have previously been identified in the Ti/Al/Cr system: These alloys exhibit excellent resistance to oxidation and are generally compatible with the $\gamma$ substrate alloys. However, prior to the development of the present Ti/Al/Cr alloy, the alloys in this system had been found to be extremely brittle.

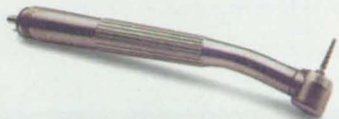
A Ti/Cr/Al coating alloy developed at NASA Lewis exhibits excellent compatibility with substrates and some improvement in mechanical properties, without sacrifice of resistance to oxidation. The alloy composition, Ti/51.25Al/12.25Cr (the numbers indicate atomic percentages), was selected so that the microstructure consists of the $\gamma$ phase with a minor volume of the oxidation-resistant Laves phase $Ti(Cr,Al)_2$. By basing the coating alloy on the $\gamma$ phase, one optimizes mechanical properties and compatibility with $\gamma$ substrates. The volume fraction of the Laves phase is kept to a minimum because it is extremely brittle.

The Ti/51.25AI/12.25Cr coating alloy was applied to a substrate of the $\gamma$ alloy Ti/48Al/2Cr/2Nb by low-pressure plasma spraying. Oxidation tests at temperatures of 800 and 1,000 °C in air indicated that the coating alloy successfully protected the substrate from oxidation (see figure). Evaluation of the isothermal fatigue behavior of the coated substrate at high temperatures in air is in progress.

The fundamental studies that led to the development of the Ti/51.25Al/12.25Cr alloy also provided a basis for the selection of new oxidation-resistant Ti/Al/X alloys. One such alloy is Ti/53Al/11Fe. This alloy is potentially useful as a reaction barrier between conventional FeCrAlY oxidation-resistant coatings and $\gamma$-TiAl-based substrates. FeCrAlY coatings are not chemically compatible with titanium aluminides, and form brittle reaction products. The Ti/53Al/11Fe alloy

## THINGS THAT SEEM TO LAST AN ETERNITY

*a. Fruitcake*



*b. Root canal*

*c. Opera*

*d. Parts lubricated with Krytox®*

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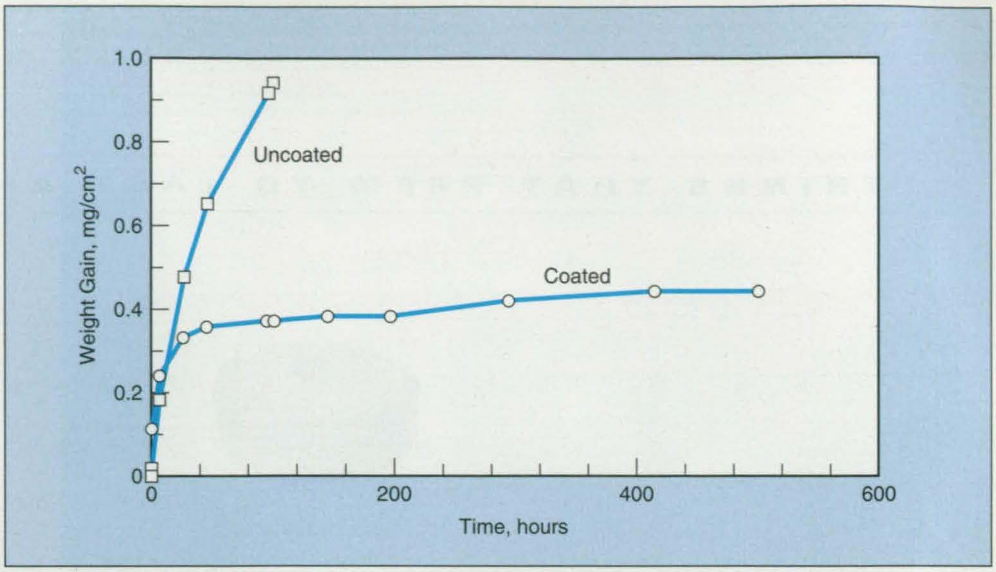
would be an excellent reaction barrier because its Fe content is intermediate between the Fe contents of the coating and substrate, and because it resists oxidation.

*This work was done by Michael P. Brady of the National Research Council and James L. Smialek and William J. Brindley of* **Lewis Research Center**. *For further information, **write in 79** on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Rd., Cleveland, OH 44135. Refer to LEW-20003.*




These **Plots of Weight Gains** show data from an experiment on uncoated and Ti/51.25Al/12.25Cr-coated Ti/48Al/2Cr/2Nb substrates in air at a temperature of 800 °C in a furnace. At each data point, the specimen was cooled in air to room temperature, weighed, and returned to the furnace. The data indicate that the coating protected the substrate from oxidation.

# Copper/Graphite Composites Made With Metal Carbide Coatings

## Better composites can be produced at lower cost.

*Lewis Research Center, Cleveland, Ohio*

A novel method of mass-producing copper-matrix/graphite-fiber composite materials involves coating the fibers with suitable metal carbides, then infiltrating fiber preforms with molten copper. The copper/graphite composites produced by this method are superior to those made by older methods, and the cost of production is lower.

Copper/graphite composites are well-suited for use in advanced thermal-management applications (e.g., heat-sinking structural supports for microelectronic circuits). When a copper/graphite composite is made with high-thermal-conductivity graphite fibers, its thermal conductivity can exceed that of pure copper. Copper/graphite composites also offer lower densities and greater stiffnesses, relative to pure copper. Yet another advantage of copper/graphite composites arises from the negative coefficients of thermal expansion of graphite fibers; by adjusting the proportions of copper and graphite and the distributions of graphite fibers, one can tailor the thermal expansions of the composites to match those of other materials.

Heretofore, it has been difficult to produce copper/graphite composites because graphite is not wet by molten copper. Some prior methods involve the addition of alloying agents to copper or coating the fibers with metal-based alloys or compounds to enhance wetting, but these methods introduce undesirable effects; for example, some cause reductions in thermal conductivity, while others cause chemical reactions that degrade the fibers.

Other prior methods involve, variously, high-pressure infiltration of molten copper into fiber preforms or hot pressing of copper-coated fibers into consolidated forms to overcome the surface-tension forces that prevent wetting. The composites made by these high-pressure methods tend to swell and develop voids when exposed to high temperatures.

In the present method, graphite fibers are coated with metal carbides that are wet by molten metals, including copper. The coating material used in most of the experiments to develop the method was molybdenum carbide, which was chosen because it offers the advantages of low density, low solubility in copper, and relatively low cost.

In a given case, the carbide, or else a metal or other layer that is a precursor to the carbide, can be deposited on the fibers by any of a number of processes; for example, sputtering, chemical vapor deposition, or electrodeposition from a molten salt. The precursor can then be reacted on or with the fiber surfaces to produce the carbide coats. For example, molybdenum metal can be deposited on the surfaces of the fibers by chemical vapor deposition, then reacted with the underlying fibers in a heat treatment to obtain molybdenum carbide coats.

A preform made of coated fibers can be made into a copper-matrix composite by immersing it in molten copper. Because the coating material is wettable, the preform becomes spontaneously infiltrated with the molten copper, without need for high applied pressure. As a result, copper/graphite composites can be mass-produced by relatively simple casting techniques; the cost and complexity of production by this method are reduced, relative to older high-pressure methods that involve such techniques as pressure casting, squeeze casting, hot pressing, and hot isostatic pressing.

Unlike copper/graphite composites made by older methods, the composites made by the present method exhibit no degradation of mechanical, electrical, or thermal properties after prolonged exposure to high temperatures or to thermal cycling. No dimensional hysteresis is observed during thermal cycling. Moreover, the composites made by the present method can be remelted and recast without detrimental effects.

*This work was done by Joseph K. Weeks, Jr., Jared L. Sommer, and Todd E. Jarman of Technical Research Associates, Inc., for* **Lewis Research Center**. *For further information,* ***write in 71*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16103.*

# CEMCAN — Ceramic Matrix Composites Analyzer

**Behavior can be analyzed from the constituent level to the ply level.**

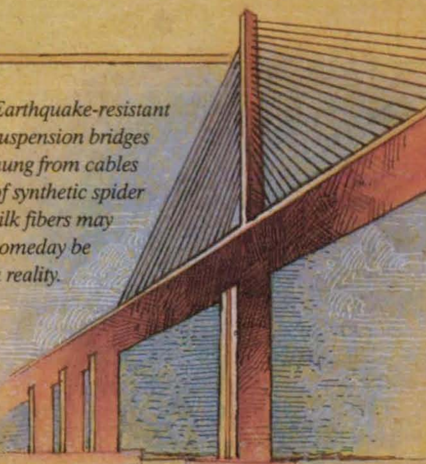
*Lewis Research Center, Cleveland, Ohio*

CEMCAN (CEramic Matrix Composites ANalyzer) is a computer program that was developed for analyzing fiber-reinforced ceramic-matrix composite materials. CEMCAN incorporates micromechanics, macromechanics, and laminate theories to enable a comprehensive point analysis of the behavior of a composite material.

CEMCAN uses a novel fiber substructuring technique that enables more accurate micromechanical representation of interfacial conditions, and at the same time provides a higher degree of detail of microstresses at a very high computational efficiency. One can evaluate the effects of interfacial conditions, fiber/matrix breakage, fabrication parameters, degradation of material performance due to environment, and other effects at a laminate level. CEMCAN also provides stress/strain relations up to failure, accounting for redistribution of stresses as matrices in these composites are brittle and start cracking at relatively low stress levels. Such a comprehensive capability from the constituent level to the laminate level does not exist in another computer code for brittle-matrix composites.

CEMCAN is written in FORTRAN 77 for Sun4-series computers running Solaris 2.x. A sample executable code is included on the distribution medium. COSMIC has successfully converted the FORTRAN 77 code to C language by use of the utility program f2c and has tested the code on a Zenith Z-station VP computer with a Pentium 75 central processing unit running Linux 1.3.71 using gcc v2.7.0 and libc v5.0.9. A math coprocessor is required to run CEMCAN under Linux. The binaries and library files for f2c are available to the public. Details are available from COSMIC. The standard distribution medium for CEMCAN is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (Sun QIC-24) in UNIX tar format. Alternate distribution media are available upon request. This version of CEMCAN was released to COSMIC in 1996.

*This program was written by P. Murthy and C. Chamis of* **Lewis Research Center** *and S. K. Mital of University of Toledo. For further information,* ***write in 20*** *on the TSP Request Card. LEW-16327*



*Earthquake-resistant suspension bridges hung from cables of synthetic spider silk fibers may someday be a reality.*

***The orb-weaving spider produces one of the world's toughest fibers. Using recombinant DNA technology, DuPont scientists have created synthetic spider silk as a model for a new generation of advanced materials.***

It has been suggested that a single strand of spider silk, thick as a pencil, could stop a 747 in flight. Whatever comparison you use, the dragline silk of the orb-weaving spider is an impressive material. On an equal weight

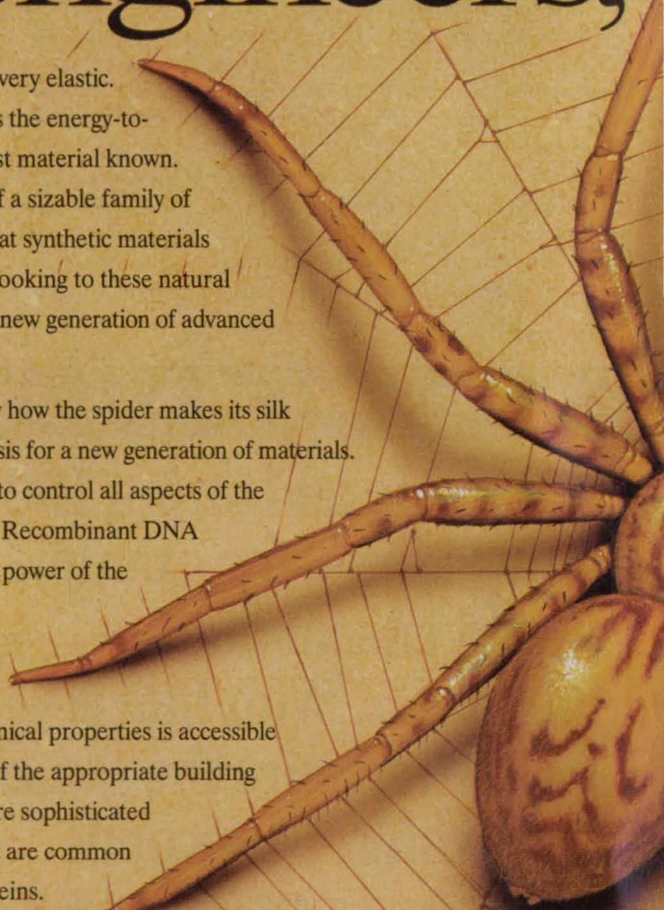
# Fiber engineers,

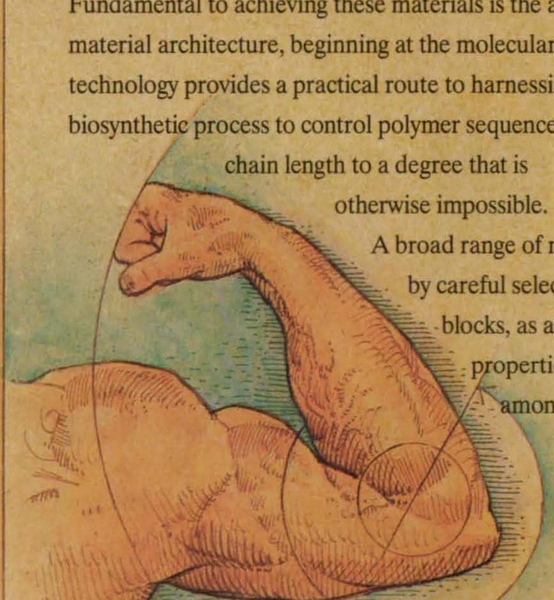
basis, it is stronger than steel. In addition, spider silk is very elastic. It is this combination of strength and stretch that makes the energy-to-break of spider silk so high. Simply put, it is the toughest material known.

Spider silk is merely the most dramatic example of a sizable family of biopolymers possessing a combination of properties that synthetic materials cannot yet approach. At DuPont, our researchers are looking to these natural materials as paradigms for the design and synthesis of a new generation of advanced structural materials.

***Secrets of spider silk, unraveled.*** Learning exactly how the spider makes its silk is important because this knowledge can serve as the basis for a new generation of materials. Fundamental to achieving these materials is the ability to control all aspects of the material architecture, beginning at the molecular level. Recombinant DNA technology provides a practical route to harnessing the power of the biosynthetic process to control polymer sequence and chain length to a degree that is otherwise impossible.

A broad range of mechanical properties is accessible by careful selection of the appropriate building blocks, as are more sophisticated properties that are common among proteins.





*What makes spider silk so tough? A unique combination of strength and stretch.*

# Advanced Composites, Plastics & Metals

Instrument Specialties, Delaware Water Gap, PA, has introduced extrudable EPDM-based **conductive elastomers** for EMI/RFI shielding and environmental sealing in semiconductor manufacturing equipment, medical electronics, and computer drive belts. Because they can be extruded into hollow-core profiles, the elastomers offer low compression forces and a broad operating range.

Compatibility with polar fluids and resistance to fluid intrusion, ozone, weathering, tearing, and abrasion make them suitable for applications where silicone and floursilicone cannot be used. Available conductive fillers include silver-plated nickel, which provides shielding effectiveness of >100 dB; silver-plated aluminum for >90 dB; silver-plated glass for 75-80 dB; nickel-plated graphite for >70 dB; inert aluminum for >50 dB; and carbon for >30 dB.

**For More Information Write In No. 736**

Mearthane® **conductive polymers** from Mearthane Products Corp., Cranston, RI, are abrasion resistant, feature the coefficient of friction of polyurethane, and can store or dissipate an electrical charge at varying levels of resistivity. The conductive urethane polymers are used in components for chart recorders in sensitive environments; vehicle wheels; static management for semiconductor manufacturing; electrostatic dissipative parts bins, enclosures, seals, and sheet materials; and insulators for medical devices.

The elastomers use 0.1% to 10% liquid conducting additives by weight, ensuring even distribution of electrical properties without degrading the polyurethane's natural strength, resilience, thermal stability, and other physical properties.

**For More Information Write In No. 732**

Nuclear Metals, Concord, MA, offers **metal powders** produced from titanium, zirconium, aluminum, common steels, stainless steels, and cobalt- and nickel-based superalloys. The powders feature high yields within a narrow particle size range for use in orthopedic and dental implants, and low-density metal matrix composites.

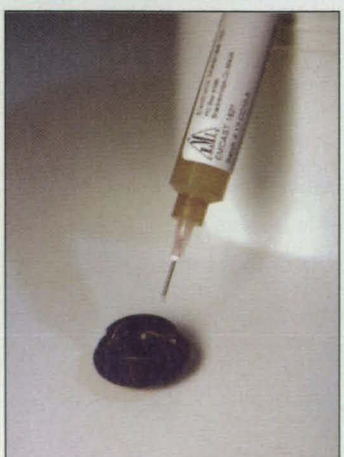
Particle size ranges from 1000 microns to 45 microns. The highly spherical powders are free of nonmetallic contaminants, enabling their use as coatings and for powder metallurgy consolidation techniques. The powders are manufactured in an inert atmosphere with cleanroom processing.

**For More Information Write In No. 731**

Ametek Specialty Metal Products Div., Wallingford, CT, offers HIVOL™ silicon carbide **aluminum composites** in simple and complex fabricated shapes and in most net-shaped parts. HIVOL is a 68% by volume fraction alpha silicon carbide composite available in two metal matrix versions: HIVOL B, a 2014 aluminum matrix; and HIVOL C, an aluminum/12% silicon matrix.

The composites can be supplied in plated or unplated versions and are suitable for electronic applications such as chip mounting, heat sinks, circuit boards, power supplies, lids, covers, and thermal spreaders. They are also used in personal computers, radar and telecommunications systems, and electric vehicle prototypes.

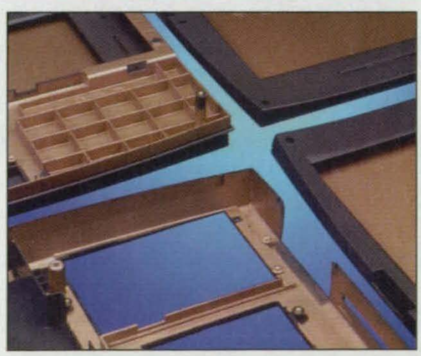
**For More Information Write In No. 741**



Electronic Materials, Breckenridge, CO, has introduced the Emcast 1820 Series of ultraviolet **epoxies**, which provide resistance to water and other forms of moisture, and contain no solvents. The 100% solid epoxy systems are designed for use as adhesives, coatings, and sealants. They cure to solvent- and chemical-resistant adhesives with minimum shrinkage upon exposure to safe long-wave UV light.

The series consists of the 1820, 1821, 1822, and 1823, which all vary in areas of hardness and Tg. Also available are UV, UV/heat, and visible light cure epoxies for use in electronics manufacturing.

**For More Information Write In No. 733**



CHO-SHIELD® 2052 **plastic coating** from Chomerics, div. of Parker Hannifin, Woburn, MA, provides EMI shielding on plastic enclosure materials such as polycarbonate, ABS, PC-ABS, Noryl, and PVC. The conductive coating consists of silver-plated-copper particles dispersed in a one-component, acrylic resin system. The coating is compatible with commercial application technologies, including high-volume/low-pressure spray systems and propeller-agitated pressure pots.

The abrasion-resistant coating is stable at high and low temperatures, and in high humidity and moderate salt fog environments. It is available in quart, gallon, and five-gallon containers; prices range from $85 to $100 per gallon.

**For More Information Write In No. 735**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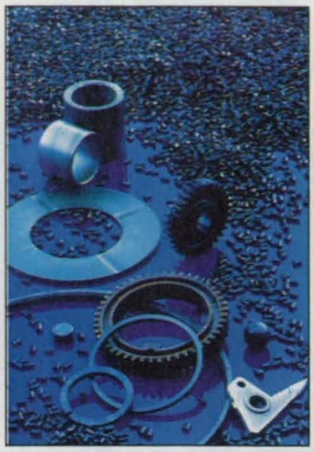
# Advanced Composites, Plastics & Metals



AURUM **thermoplastic polyimide** from Mitsui Toatsu Chemicals, Purchase, NY, features heat resistance to 288°C, tensile strength to 39,000 psi, and is injection-moldable. Applications in the automotive, machinery, aerospace, and semiconductor equipment industries include jet engine components, check valve balls, spline couplings, heat-resistant gears and vanes, carriers for aluminum hard disks and silicon wafers, and bearing retainers.

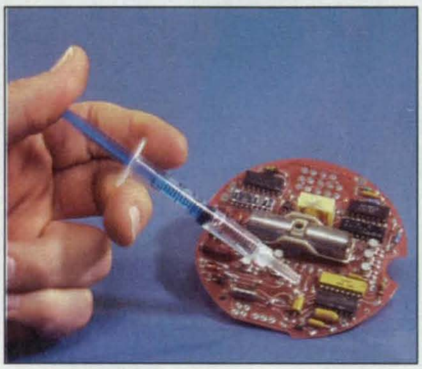
The engineering plastic is available in molding pellets and powder, film, extruded stock shapes, monofilaments, metal/polyimide laminates, thin-wall tubing, and composite prepegs. It provides tight tolerancing without machining or post-curing.

**For More Information Write In No. 737**

Duratron™ HP **heat-resistant plastic** from Polymer Corp., Reading, PA, can be machined into dimensionally stable structural parts designed for continuous use at temperatures to 304°C. The polyimide is available in rods, bars, and plates, and features low outgassing, low levels of ionic impurities, and resistance to aromatic hydrocarbons, acids, and bases. Applications in the semiconductor manufacturing industry include melt-resistant insulators and connectors, and for parts in plasma arc etching chambers.

Also available are two lubricated bearing grades: Duratron 150, which contains 15% graphite; and Duratron 400, which has 40% graphite. The graphite-lubricated materials are used in applications such as severe-service bearings, where little or no lubrication is possible and temperatures exceed 260°C.

**For More Information Write In No. 734**



Master Bond, Hackensack, NJ, has introduced EP30LTE two-part **epoxy**, which cures at room temperature or more rapidly at elevated temperatures. It features a thermal expansion coefficient of less than $12 \times 10^{-6}$ in/in/°C and shrinkage upon cure of less than 0.0002 in/in.

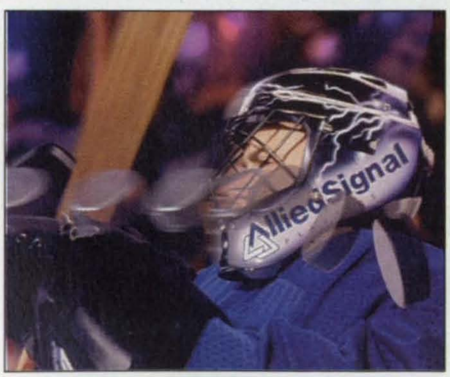
The epoxy is suited for applications that are exposed to repeated rapid environmental changes. It produces bonds to both similar and dissimilar substrates and is chemical resistant. The 100% solid system does not contain solvents or diluents, is an electrical insulator, and is available in 1/2-pint, pint, quart, gallon, and five-gallon kits.

**For More Information Write In No. 738**

GAR-DUR® **plastic polymer** from Garland Manufacturing, Saco, ME, is an ultra-high-molecular-weight plastic material available in a variety of shapes, including bars and boards over 10' in length, rods up to 8" in diameter, tube stock to 6-1/2" in diameter, tape, and custom profiles. The material is abrasion resistant, self-lubricating, impact resistant, reduces noise and vibration levels in machinery, and is resistant to rust and corrosion.

Applications include rollers, gears, sprockets, valves, bushings, bearings, chain guides and rails, and machine components. It is FDA- and USDA-approved for food and beverage applications and has a coefficient of friction of 0.14. The material is thermal stable in temperatures from -273°C to +93°C.

**For More Information Write In No. 739**




AlliedSignal Plastics, Morristown, NJ, has introduced UltraTough™ Capron® HPN glass-reinforced **resins** in grades that provide from 15 to 40% glass reinforcement, with one grade that also provides 40% mineral reinforcement. Applications include parts used in the automotive, power equipment, and protective equipment industries.

Six types of resins are available: the Capron® HPN 9315G, 9325G, 9333G, 9340G, 9350G, and 9362G. They are heat resistant and feature fast flow-in and freeze-off in injection molding production.

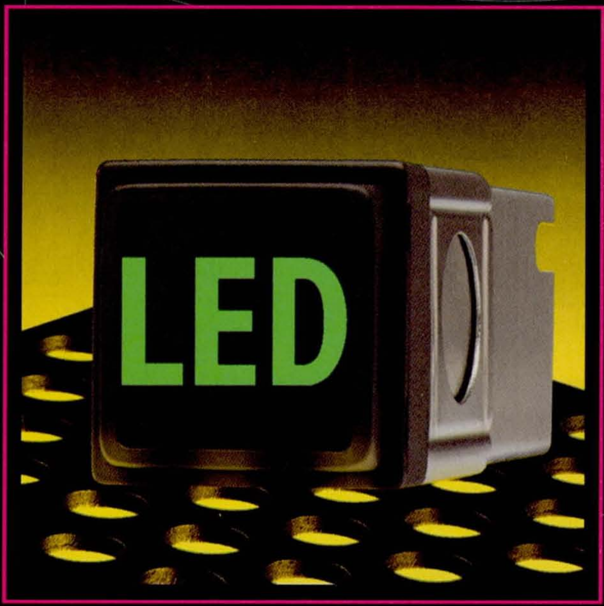
**For More Information Write In No. 740**

DuPont Engineering Polymers, Wilmington, DE, offers two **resins**: Zenite™ liquid crystal polymer resin and Crastin® 93 PBT thermoplastic polyester resin. Zenite LCP resin is suited for high flow to fill detailed components and features high temperature resistance, dimensional stability, mechanical strength, and UL94 V0 and IEC 85 recognition.

Crastin is available in two glass-reinforced grades: LW9330 with 30 percent glass fiber reinforcement; and LW9320 with 20 percent glass fiber reinforcement. The resins are made using a proprietary alloying technology and provide low specific gravity and minimal warpage.

**For More Information Write In No. 730**

# Announcing the First LED Sunlight Readable, Mil-Spec Switch

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**For More Information Write In No. 622**

# Improved Capacitive Gap Sensors for Micromachined Devices

## Shielding electrodes would suppress capacitive coupling with the micromachined semiconductor material.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

An improvement has been proposed for the capacitive sensors that are used to measure displacements between structural members in micromachined electromechanical sensors and actuators. These micromachined devices are made largely of semiconducting materials (usually silicon), the electromagnetic properties of which vary with temperature and with electric fields, including the electric fields of the capacitive sensors. In a typical device of this type, the capacitive coupling with the semiconducting material therefore introduces spurious temperature- and electric-field-dependent signal components that degrade the accuracy of the capacitive measurement of displacement (see Figure 1). The proposed improvement would eliminate these spurious signal components.

The proposed improvement is based on the shielding-electrode concept, (shielding electrodes have also been called "guard" electrodes), which has been used for many years and in many different applications to suppress spurious capacitive coupling. Instead of mounting the sensing electrodes in nearly direct contact and in close capacitive coupling with the micromachined semiconductor substrates, the sensing electrodes would be incorporated into sandwich structures that would include shielding electrodes interposed between the sensing electrodes and the semiconductor substrates (see Figure 2). A layer of dielectric material (which would be relatively insensitive to temperature and electric field) would separate each sensing electrode from its shielding electrode, and another layer of the dielectric material would separate the shielding electrode from the substrate.

Of the circuit configurations that could be used to implement the shielding electrode principle, the one shown in Figure 2 is conceptually the most straightforward (though not necessarily the most practical). By use of a high input-impedance, unity-gain buffer amplifier, each shielding electrode would be driven at the same voltage as that applied to the associated sensing electrode. This arrangement would effectively eliminate capacitive coupling between the sensing electrode and the semiconductor substrate; each sensing electrode would be capacitively coupled only to the other sensing electrode and other nearby objects on the side facing away from the shielding electrode.

*This work was done by Benjamin P. Dolgin, Frank T. Hartley, and Paul M. Zavracky of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 5*** *on the TSP Request Card.*
*NPO-19739*

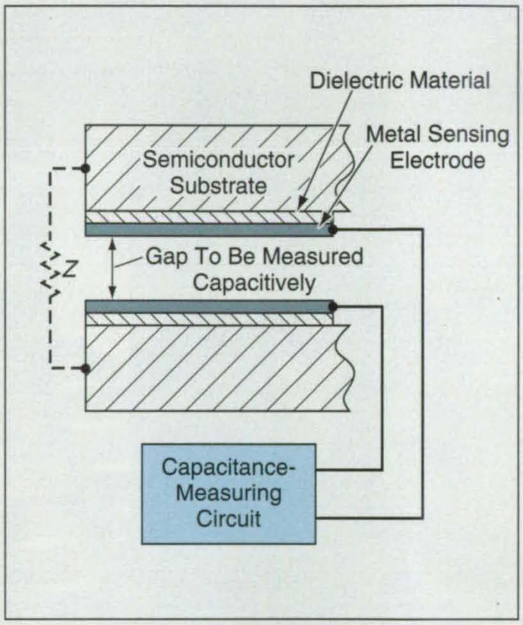


Figure 1. **Capacitive Coupling** between the sensing electrodes and the semiconductor substrates introduces spurious temperature- and electric-field dependent signal components (represented here as originating in the additional series impedance Z).

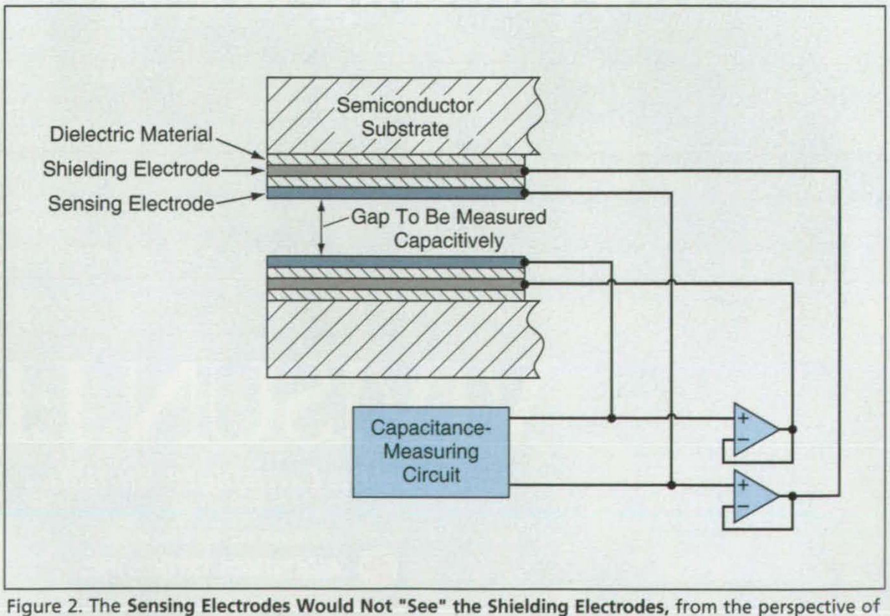


Figure 2. The **Sensing Electrodes Would Not "See" the Shielding Electrodes,** from the perspective of capacitive coupling, because the shielding electrodes would be driven at the same potentials. Because of the shielding effect, the sensing electrodes would also not "see" the semiconductor substrates. However, the sensing electrodes would "see" each other, as desired.

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**For More Information Write In No. 552**

# Selectable PCM Format Generator

*John F. Kennedy Space Center, Florida*

The Selectable Pulse-Code-Modulation (PCM) Format Generator ("SPF Generator," for short) is a portable, lightweight test apparatus used to verify the capability of ground support equipment (GSE) prior to connecting the GSE to telemetric flight electronic equipment, and to verify the proper operation and configuration of demultiplexers. The SPF Generator was developed to replace a PCM Simulator that had to be programmed anew, by use of push-button panel switches, for each new telemetry-data format. By means of a switch, the SPF Generator can be made to use either a clock signal generated externally or a clock signal generated internally by a crystal oscillator, counters, and comparators. The clock signal is used to control address counters in an Erasable Programmable Read-Only Memory (EPROM). There are six EPROMs, one of which is selected via a rotary switch to select the required data format. At each address, a byte of information is read from the chosen EPROM and sent to a parallel-in/serial-out shift register. The data are then transformed into emitter-coupled-logic-level signals for an interface with the GSE. A computer program written to facilitate the use of the SPF Generator prompts the user for input parameters needed to construct a telemetry file, then programs the file into the EPROMs.

*The hardware was designed by Diana Manent and the software was written by Torrey Maggard, and José J. Amador of* **Kennedy Space Center**. *For further information,* ***write in 58*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11842.*

# Successive-Approximation ADCs With Capacitive Coupling

## These circuits could be incorporated into focal-plane arrays of photodetectors.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Two closely related types of ultra-low-power, successive-approximation analog-to-digital converter (ADC) circuits with capacitive coupling are undergoing development. These are prototypes of ADC circuits that are to be incorporated into integrated-circuit focal-plane arrays of photodetectors in advanced video cameras. The incorporation of these ADCs would contribute to miniaturization and to reduction in the number of integrated circuits and would provide digital output without need for separate ADC circuits, while maintaining high speed and low power dissipation.

The basic concept of a successive-approximation ADC has long been known and can be summarized as follows: An input voltage ($v_{in}$) that one seeks to represent digitally is compared with a known voltage ($v_{out}$) that has been generated by a digital-to-analog converter. A succession of such comparisons is made, starting with the most significant bit and proceeding toward the least significant bit. At each comparison, the next, less significant bit for next comparison is adjusted according to whether $v_{in}$ is greater or less than $v_{out}$. Thus, $v_{out}$ is made to converge toward $v_{in}$ in steps and, equivalently, the precision of the digital representation increases in steps. A succession of $n$ such comparisons yields a digital representation of $v_{in}$ with a precision of $n$ bits. In cases in which precision no greater than 10 bits is needed, the small number of comparisons offers an advantage of high speed and low power dissipation.

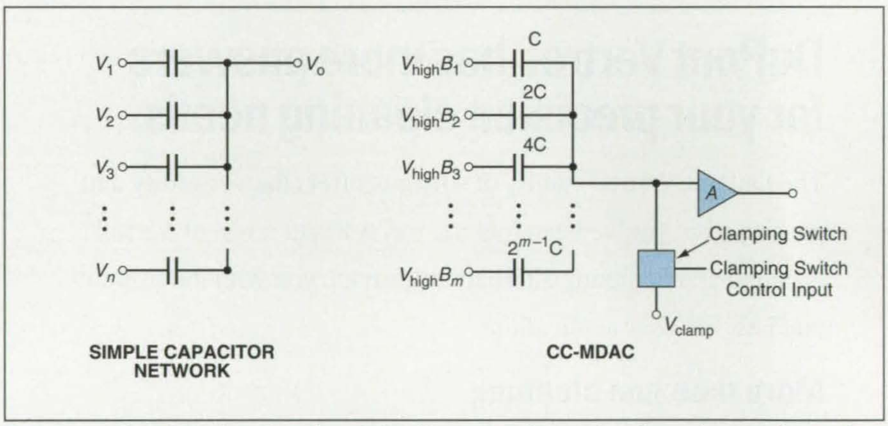


Figure 1. A **CC-MDAC** is based on the relationship among changes in voltages in a simple capacitor network.

For generating known voltages to be compared with input voltages, the developmental ADCs utilize capacitively coupled multiplying digital-to-analog converters (CC-MDACs). A CC-MDAC is based on the relationship between the change ($\Delta$) in each of the input voltages $V_j$ ($j$ = 1 to $m$) and the change in the output voltage $V_o$ of the simple capacitor network shown in the left part of Figure 1. It can easily be shown that

$$\Delta V_o = \frac{\sum_{j=1}^{m} C_j \Delta V_j}{\sum_{j=1}^{m} C_j}$$

In a CC-MDAC, shown on the right, the bit lines are coupled via capacitors to the input node of a high-input-impedance amplifier. The capacitor for the second bit has twice the capacitance of that for the first bit, the capacitor for the third bit has four times that for the first bit, and so forth.

Initially, all bits are set to zero (represented by zero voltage) and the clamping switch is turned on momentarily to set the amplifier input node at an initial potential of $V_{clamp}$. Next, each bit is set to its assigned value of zero or one, a one being represented by a voltage $V_{high}$ on the bit line. Using the equation shown above, it can be shown that the resulting output potential of the CC-MDAC is given by

$$v_{out} = A[V_{high}(B_1 + 2B_2 + 4B_3 + \ldots 2^{m-1}B_m) + V_{clamp}]$$

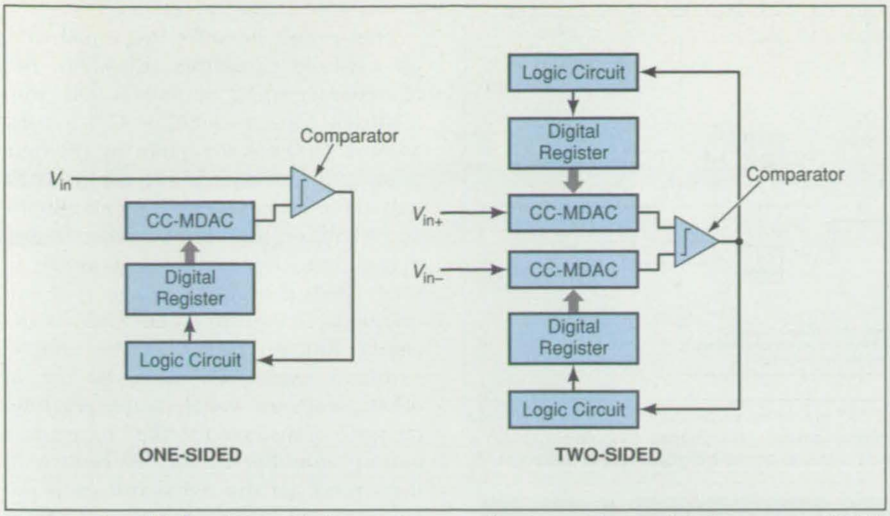


Figure 2. **One-Sided and Two-Sided** successive-approximation analog-to-digital converters (ADCs) with capacitive coupling are undergoing development. Functional units of both types have been constructed.

where $A$ is the voltage gain of the amplifier and $B_j$ denotes the value (0 or 1) of the $j$th bit.

Figure 2 illustrates the two types of developmental successive-approximation ADCs containing CC-MDACs. The one-sided version could be used for nondifferential or differential input; the two-sided circuit is better suited to differential input. In the case of differential input in the one-sided version, one side of the input could be used to establish $V_{clamp}$. Any error associated with the clamping voltage and/or caused by voltage offset in the comparator can be corrected digitally, either by incorporating a corrective offset into the digital input to the CC-MDAC, or by similarly offsetting the digital output. The two-sided version may prove to be inherently less affected by comparator offset and clamping errors.

*This work was done by Eric Fossum and Zhimin Zhou of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 37*** *on the TSP Request Card.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

*Larry Gilbert, Director*
*Technology Transfer*
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*Refer to NPO-19783, volume and number of this* NASA Tech Briefs *issue, and the page number.*

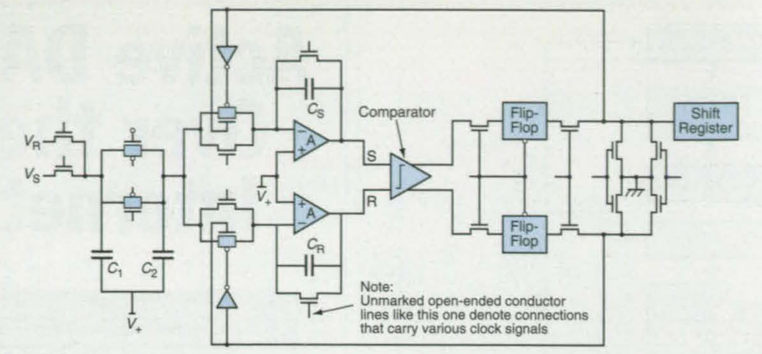
## Successive-Approximation ADCs With Charge Balancing

### These circuits implement an alternative approach to successive approximation.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The figure illustrates a complementary metal oxide/semiconductor (CMOS) analog-to-digital converter (ADC) of a type that is undergoing development for eventual incorporation into focal-plane arrays of photodetectors. This circuit can be used as an alternative to the circuits described in the preceding article, "Successive-Approximation ADCs With Capacitive Coupling" (NPO-19783). A functional 10-bit prototype of this circuit fits within an area 24 μm wide and 3.8 mm long.

This circuit offers the same advantages as do those described in the preceding article, and like those circuits, this one is based on the concept of successive approximation. However, this circuit differs from those of the preceding article in that it implements successive approximation according to a charge-balancing approach, in which two branches of the circuit successively accumulate successively halved increments of charge in an attempt to balance the charges in the two branches.




This **Circuit Strives To Balance Charges** in its "R" and "S" branches, successively adding successively halved fractions of a reference charge to whichever branch contains less charge. By going through $n$ cycles of comparison and increment of charge, the circuit achieves an $n$-bit digital representation of $V_S$.



This circuit includes two equal sample-and-hold capacitors ($C_1 = C_2$), two charge-integrating amplifiers ($A$) with feedback capacitors ($C_R = C_S$), a comparator, flip-flops for buffering the digital output feedback to the input terminals of the charge-integrating amplifiers, and a shift register. Initially, the charges in both branches of the circuit are set to zero. Next, the signal voltage ($V_S$) that one seeks to digitize is converted to the charge domain by use of the sample-and-hold capacitors. Then by use of other electronic switches, the resulting charge is transferred to the charge-integrating amplifier in the "S" branch of the circuit. (If the signal voltage is differential instead of one-sided as shown in the figure, then the voltage from the second signal line is similarly converted to charge and put onto the "R" branch of the circuit.) Next, the reference voltage ($V_R$) is similarly converted to a reference charge, which is then split in half by use of $C_1$, $C_2$, and the electronic switches between them.

A sequence of comparisons of charges in the "R" and "S" branches then begins. After the first comparison, the 1/2 reference charge is transferred from $C_2$ to whichever branch contains less charge (as indicated by the output of the comparator). The 1/2 reference charge that remains on $C_1$ is then split into two 1/4 reference charges. The charges on the two branches are again compared, and the 1/4 reference charge on $C_2$ is transferred to the branch that contains less charge. This process is repeated to obtain an $n$-bit digital representation of the signal voltage: The first comparison represents the most significant bit and each successive comparison represents the next less significant bit. Each time the "R" branch is selected to receive half of the remaining fraction of reference charge, the corresponding bit is set to "1"; otherwise, it is set to zero.

*This work was done by Eric Fossum, Bedabrata Pain, and Zhimin Zhou of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 38*** *on the TSP Request Card.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

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*Refer to NPO-19784, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# A Planar Separate-Bias Scheme for SHP Two-Diode Waveguide Mixers

**Bias connections are made via a compact trilayer metal/insulator/metal planar filter structure that functions as a single-layer filter and yet provides separate dc path for each diode.**

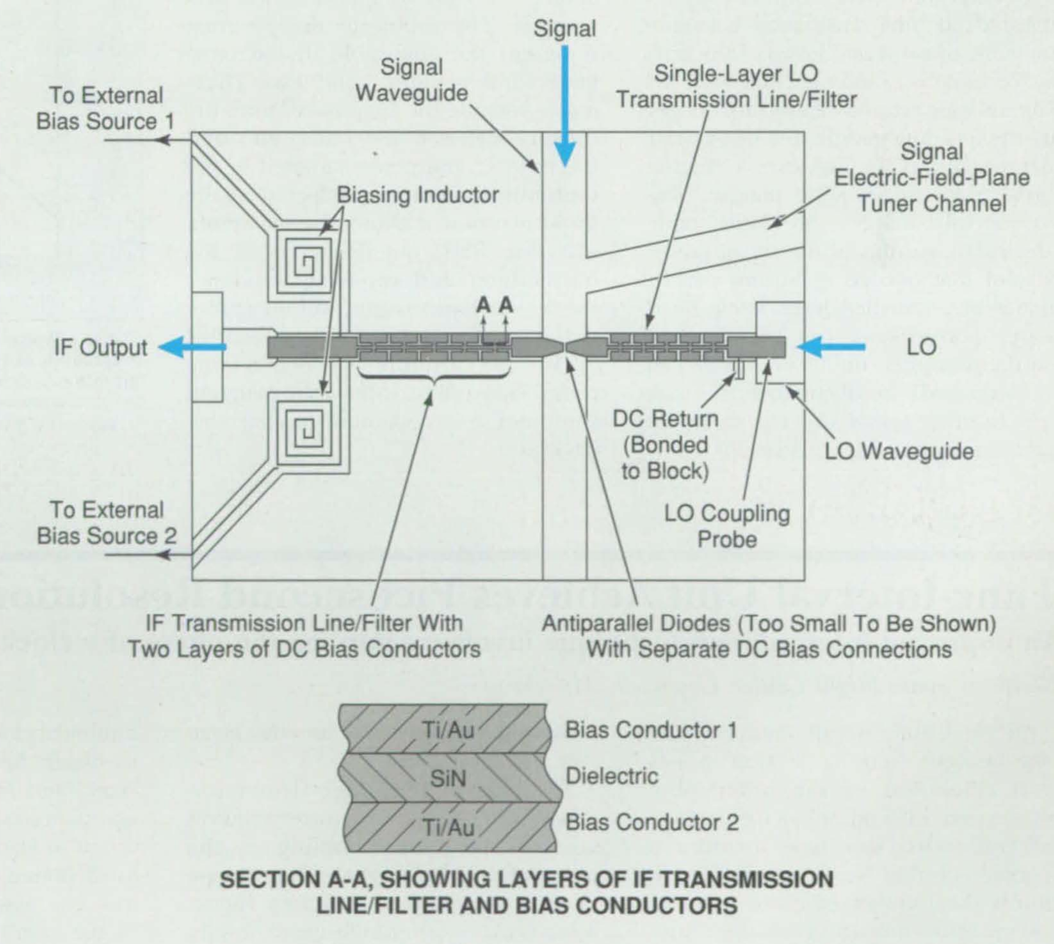
*NASA's Jet Propulsion Laboratory, Pasadena, California*

A very compact arrangement for the individual biasing of two antiparallel planar Schottky diodes in a waveguide-based subharmonically-pumped (SHP) mixer has been proposed and tested. SHP mixers require a local oscillator (LO) at half the signal frequency (RF) to produce intermediate-frequency (IF) output and are often preferred at very high frequencies where the LO power for fundamentally-pumped mixers is unavailable, and yet, SHP mixers without individual bias require 2 to 4 times more LO power, albeit at a lower frequency, than fundamental mixers. To reduce the LO power requirements for SHP mixers, separately-biased diodes have been used in prior circuit implementations. However, these implementations have needed extra ports and fairly large bypass capacitors for dc isolating the devices. The concomitant increase in the size and complexity of the circuitry makes such implementations unattractive for high-frequency waveguide mixers. The present scheme utilizes the vertical space in a waveguide channel resulting in a compact, stripline-coupled biasing circuit.

A separate-bias concept has been implemented in both a 200- and a 640-GHz SHP mixer that includes a split waveguide block and a quartz-substrate stripline circuit (see figure). The block is based on a prior SHP mixer design, requiring only minor modifications for adding the separate-bias capability. The stripline circuit consists of an LO bandpass filter/transmission line, two antiparallel diodes, and a novel metal/insulator/metal trilayer IF low-pass filter/transmission line. The dc connection to each diode is made via the two identically-patterned metal conductors of the IF circuit, each of which can be a stand-alone filter. They are stacked over the same circuit area and separated by an 8,000-Å layer of silicon nitride. The thin nitride film ensures that these conductors are capacitively coupled so that they function together as a single IF filter but are dc isolated.

Preliminary characterization of the prototype circuits in waveguide SHP mixers at 200 and 640 GHz have been completed. At 200 GHz, the application of appropriate bias can reduce the LO power requirement by 3 dB with only a 10 to 15 percent degradation in mixer performance. These results clearly indicate that this scheme is viable, and work is presently underway to optimize this design for a NASA space-borne Earth remote-sensing instrument Microwave Limb Sounder.

*This work was done by Trong-Huang Lee, Imran Mehdi, and Peter H. Siegel of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 50*** *on the TSP Request Card.*
*NPO-19832*




The **Waveguide Mixer Block** has a traditional cross-guide configuration with the IF channel and LO waveguide perpendicular to the received-signal waveguide. The separate-bias two-conductive-layer IF transmission line/filter is housed in the IF channel; a similar transmission line/filter that provides electrical coupling between the diodes and the LO waveguide is housed in the LO channel.

# Electronic Systems

## Computing Supportable Bit Rates in Radio Communications

**Designs and performances can be analyzed quickly.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A computer program quickly estimates parameters that characterize the performance of a free-space radio-communication system in which a carrier signal is modulated with binary phase-shift keying to transmit digital signals. One important performance parameter is the maximum supportable bit rate, which is the bit rate above which the system is expected to incur a bit-error rate (BER) above some specified allowable value. The program calculates maximum supportable bit rates as functions of various design parameters and operating conditions, plus other quantities that are useful in designing the system.

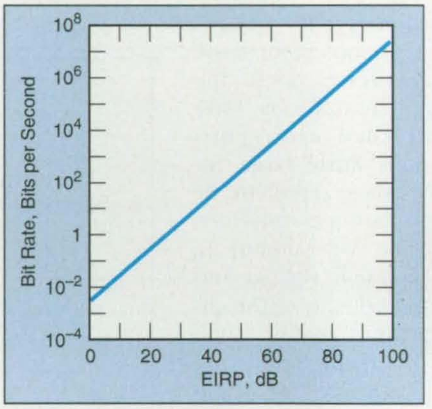
To determine the maximum supportable bit rate, one must create a systematic table of gains and losses of the link; such a table is called the "link budget." The ultimate outputs of any link budget are the link data margin, the link carrier margin, and, if the link uses a ranging signal, then the ranging margin. The various link margins are logarithmic (decibel) measures of the signal power beyond that needed to ensure performance at a specified level. For a fixed power, performance can be improved (in the sense that the bit-error rate can be decreased) by decreasing the data rate. In other words, one can trade the data rate against the link margins.

In a typical link budget, the largest gains are attributable to the directional patterns of the transmitting and receiving antennas, while greatest losses are attributable to (1) the dispersion of power in the expansion of wavefronts during propagation and (2) the equivalent noise temperature of the receiver. Smaller losses are attributable to the transmitting and receiving equipment and to atmospheric and ionospheric dispersive effects.

The computer program is based on established equations for the various gains and losses and for the relationship among the various gains, losses, and margins. The inputs to the program represent the applicable design parameters and operating conditions. These inputs include the frequency band, the distance between the transmitter and the receiver, the power radiated by the transmitting antenna, the total of all the losses mentioned above, the maximum allowable BER, the diameters of the transmitting and receiving antennas, the desired data margin, and the choice of transmitting the data either uncoded or in one of nine error-correcting codes. Given these inputs, the program computes the maximum supportable data rate.

The program is written in the Excel 5.0 software system, which was chosen because it offers excellent number-handling and charting capabilities. For example, the program can generate a plot of the maximum supportable bit rate as a function of the radiated power, as illustrated in the figure.

*This work was done by Anil Kantak and Faiza Lansing of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 35*** *on the TSP Request Card. NPO-20039*




This is a **Typical Example of the Output of the Program**. It can be used to find the maximum bit rate supported by a given effective isotropically radiated power (EIRP) or the EIRP needed to support a given bit rate.

## Time-Interval Unit Achieves Picosecond Resolution

**An improved interpolation technique involves sampling the phase of a clock signal.**

*Goddard Space Flight Center, Greenbelt, Maryland*

An electronic circuit measures the time between "start" and "stop" pulses to a resolution of the order of a picosecond. Like other electronic time-interval units, this one includes a coarse-resolution time counter (which counts the number of clock periods) and measures time to a resolution finer than one clock period by use of start-time and stop-time interpolators. The interpolators used in other time-interval units contain various sources of error that degrade the achievable accuracy and resolution.

The present time-interval unit features an improved interpolation scheme based on sampling of the phase of the clock signal. This scheme involves sampling of the clock signal, using GaAs or other high-speed, low-jitter semiconductor sampling circuitry for increased accuracy.

This time-interval unit includes a clock-signal generator, which provides a sinusoidal clock waveform at a frequency nominally between 2 and 5 GHz. The "start" and "stop" pulses typically originate as optical (laser) pulses and are converted to electrical form by photodetectors followed by fast threshold comparators. The "start" and "stop" pulses are fed to the coarse-resolution time counter, which measures the integer part, $n$, of the number of clock cycles between the pulses and thus indicates time to a resolution of one clock period, $T$.

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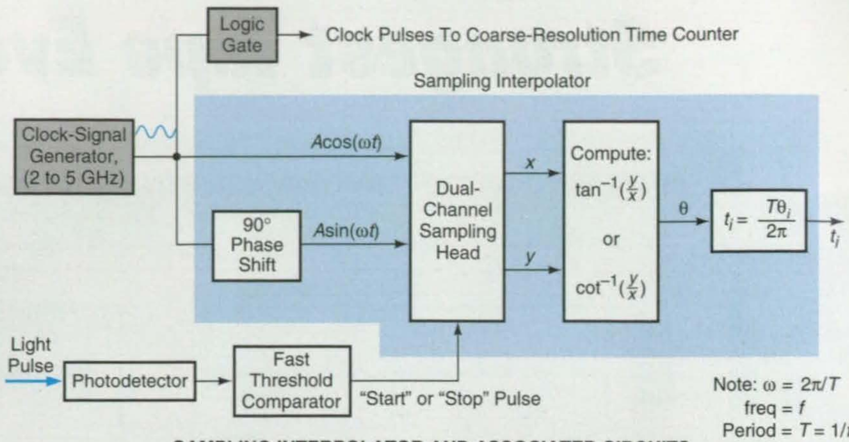
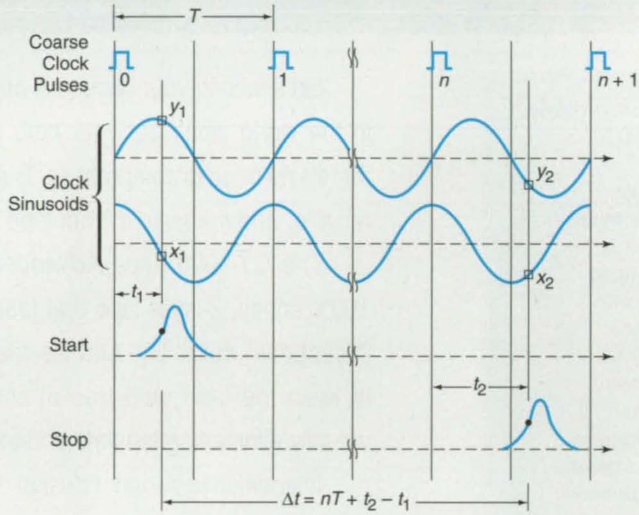



SAMPLING INTERPOLATOR AND ASSOCIATED CIRCUITS




TIME-MEASUREMENT WAVEFORMS

The **Sampling Interpolator** is one of two identical interpolators in the time-interval unit. It measures the phase angle of the clock signal at an instant associated with a "start" or "stop" pulse. This phase angle is directly proportional to the time elapsed between the beginning of the clock period and the "start" or "stop" pulse.

The pulses are also fed to the start-time and stop-time sampling interpolators, which are identical. The clock signal entering each interpolator is fed directly to one of the input terminals of a dual-channel sampling head. A 90°-phase-shifted (quadrature) version of the clock signal is fed to the other input terminal of the sampling head. When triggered by a "start" or "stop" pulse, the sampling head acquires the instantaneous values $x$ and $y$ of the in-phase and quadrature versions, respectively (see figure).

These values are fed to a circuit that computes the smaller of $|y/x|$ or $|x/y|$, as part of computing the clock phase angle at the trigger time, $\theta = \tan^{-1}(y/x)$ or $\theta = \cot^{-1}(x/y)$. The time elapsed from the beginning of the present clock period to the "start" or "stop" pulse is computed from $t_i = T\theta_i/2\pi$, where $i = 1$ for start, 2 for stop. Finally, the outputs of the interpolators are used to compute the unknown time interval $\Delta t$ between the "start" and "stop" pulses from $\Delta t = nT + t_2 - t_1$.

*This work was done by James B. Abshire of* **Goddard Space Flight Center**. *For further information,* ***write in 40*** *on the TSP Request Card.*

*This invention has been patented by NASA (U.S. Patent No. 5,566,139). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13505.*

# Beacon Monitoring Would Reduce Interactions With Remote Systems

## Communications and operations costs would be significantly reduced.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

"Beacon monitoring" denotes a concept for allowing a remote system to notify local operators when it requires interaction. Historically, remote systems with little or no intelligence have had to transmit large amounts of system status data to operators, requiring reliable communications links, lengthy transmission times, and complex data reception and detection equipment. Human operator experts must monitor and analyze these data and decide when further interaction with the remote system is required.

In the future, many remote systems will have the intelligence to analyze their status data on their own. The responsibility for deciding when interaction is required between the remote system and local operators will transfer to the remote system. The beacon-monitoring concept reduces the need for the remote system to transmit routine telemetry data and for routine operator interaction. Instead, it provides the ability for the remote system to transmit a simple message that requests one of four actions from operations:

(1) Green: Leave me alone. I am functioning normally and no interaction by operations experts is required.

(2) Red: Contact me as soon as possible. I require operations support on an emergency priority basis.

(3) Yellow: Contact me within a certain prearranged amount of time or I will start performing in a degraded mode (e.g., losing or overwriting data, running out of commands, and the like).

(4) Orange: Contact me at your convenience. An event has occurred that may be of interest to operations and that operations may want to collect information sooner than the next scheduled telemetry contact.

The first intended applications for this technology are for JPL spacecraft that are equipped with appropriate onboard monitor and decision-making intelligence (specifically, New Millennium and Pluto Express). These spacecraft will have the capability of requesting ground action by transmitting one of four beacon signals implemented as one of four possible subcarrier tone pairs or some other radio signaling scheme that is simple to generate and detect. The simplicity of the beacon signals allows detection at lower signal-to-noise ratios, with smaller receiving antennas, and with significantly less complex and expensive receiving and detection equipment than that required for traditional telemetry.

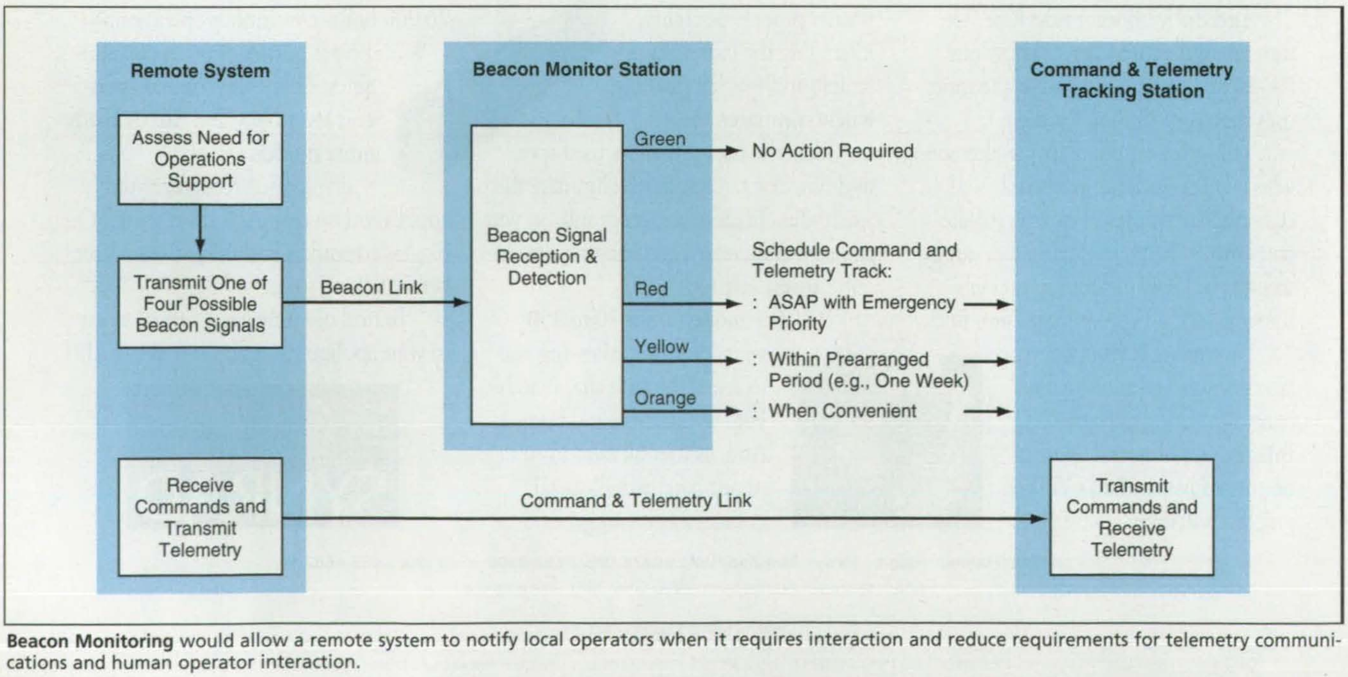
The JPL operational concept for using the beacon is that the spacecraft will point at Earth and continuously transmit one of the four beacon tones. Once a day, whenever it is convenient, the ground will monitor the beacon. If it is green, it will be logged in and the spacecraft will be ignored until the next day. If the beacon is found to be red, yellow, or orange, the ground will schedule a traditional telemetry track and command the spacecraft when to begin downlinking telemetry. The procedures for scheduling these tracks will vary as a function of the difference in urgency among the red, yellow, and orange beacons.

This new beacon-monitoring technology is projected to provide significant flight operations cost savings by:

- reducing the need to routinely downlink large amounts of status telemetry,
- reducing the human tasks associated with the capture and analysis of routine status telemetry, and
- reducing the loading on large-aperture DSN (Deep Space Network) antennas and complex telemetry reception and detection equipment.

Beacon monitor technology may be the key to enabling low cost operational support of fleets of spacecraft that may be flying simultaneously in the near future.

*This work was done by John Carraway, E. Jay Wyatt, Richard Doyle, and Bruce Crow of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 57*** *on the TSP Request Card.*
*NPO-19706*




**Beacon Monitoring** would allow a remote system to notify local operators when it requires interaction and reduce requirements for telemetry communications and human operator interaction.

# Penetrator and Dart NMR Probes

## Conventional sampling procedures would not be necessary.

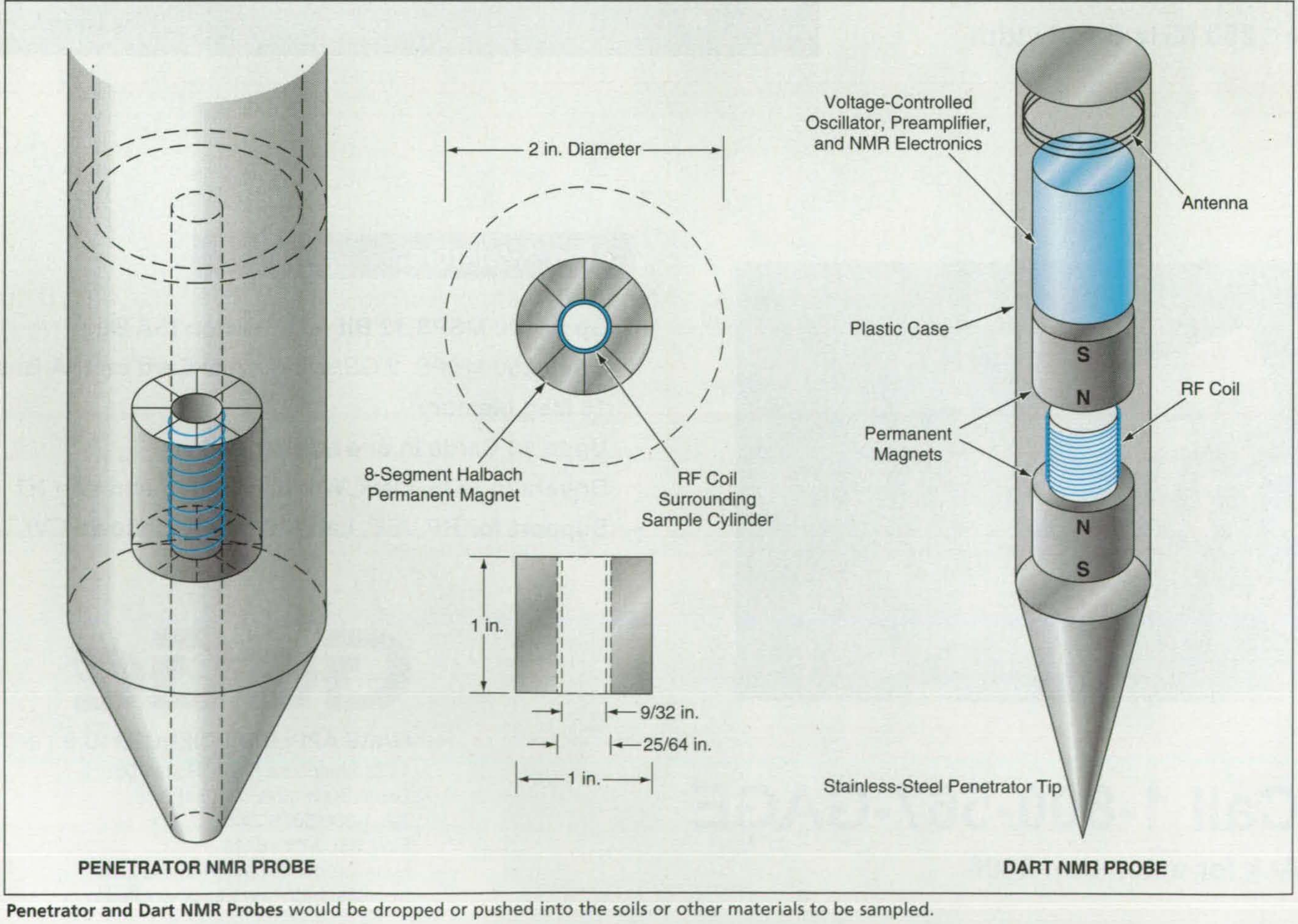
*NASA's Jet Propulsion Laboratory, Pasadena, California*

The figure shows the major parts of penetrator and dart nuclear-magnetic-resonance (NMR) probes for analyzing soils and other materials. Originally intended for use during exploration of other planets, these probes might also be useful in remote analyses of soils and other materials on Earth. The terms "penetrator" and "dart" signify that the probes would be pushed or dropped into the materials to be sampled. The use of these probes would eliminate the need for such conventional sampling procedures as scooping up samples and placing them inside NMR coils; although such procedures are easy for human technicians on location, they are difficult to perform by use of robots or telemanipulators.

A penetrator NMR probe would include a cylindrical Halbach permanent-magnet assembly surrounding a hollow cylindrical NMR radio-frequency (RF) coil surrounding a hollow sample cylinder. Three 1 × 2-in. (25.4 × 50.8-mm) surface-mount boards holding electronic signal-processing circuitry could be placed in the upper portion of the probe. Upon insertion of the probe into the material to be analyzed, either a sample of the material could be pushed up into the sample tube from the bottom opening, or else the sample could fall in from the top opening. The probe could be operated in either the continuous-wave or pulsed NMR detection mode.

In its basic principle of operation, a dart NMR probe would be similar to NMR probes that are lowered into predrilled oil-well holes to detect surrounding oil. However, a dart NMR probe would push its way into the sample material, without need for a predrilled hole. In comparison with oil-well NMR probes, a dart NMR probe would be smaller and would consume less power.

In a dart NMR probe, two cylindrical permanent magnets would be positioned astride an axial gap with opposite polarities (north poles facing each other along the axis), so that a significant part of the permanent magnetic field would reach out into the surrounding sample material. An RF coil would be placed in the gap between the magnets; the RF magnetic field would also reach out into the surrounding




**Penetrator and Dart NMR Probes** would be dropped or pushed into the soils or other materials to be sampled.

material. Like oil-well NMR probes, a dart NMR probe would be operated in the pulsed NMR detection mode; pulsed operation would help to compensate for the effects of inhomogeneity of the permanent magnetic field in the particular opposite-polarity configuration. Dart NMR probes would offer two advantages over penetrator NMR probes; there would be no need to ensure that the samples entered sample cylinders, and there would be no need for concern over plugging of sample cylinders.

*This work was done by Soon Sam Kim of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, write in 18 on the TSP Request Card. NPO-19651*

# Computing Erosion in Three-Grid Ion Thrusters

## A computer code is based on particle-in-cell and Monte Carlo concepts.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A computer code is undergoing development for use in numerical simulation of erosion of the grids in three-grid ion thrusters. When fully developed, the code will be used to analyze and design three-grid ion thrusters, which can be tailored to reduce erosion significantly below the levels of erosion observed in an older generation of two-grid ion thrusters. The code runs on PC-compatible computers and provides real-time color graphical displays that facilitate analysis and interpretation of the simulated physical phenomena as computation progresses.

The grids in an ion thruster are eroded by sputtering from charge-exchange ions produced by collisions between the primary beam ions (the ions that one seeks to accelerate) and neutral atoms. The neutral atoms come from both neutral propellant gas escaping from a plasma-discharge chamber in the thruster and from residual gas in the vacuum chamber in which the thruster is tested or operated. The computer code, which simulates these and other phenomena relevant to the grid-erosion problem, is an extended version of software that was originally developed for two-grid thrusters.

Because of the low density and the small rate of charge-exchange collisions in ion thrusters, one can use direct motion-of-particles numerical-simulation methods to model the phenomena in an ion thruster. Accordingly, the computer code incorporates two algorithms that implement particle-oriented mathematical models. One of these algorithms implements a charged-particle model according to the particle-in-cell method, in which the trajectories of a large number of particles are tracked to simulate the flow of a plasma or of ions. This model is used to simulate the ion beam and ion optics and is coupled with a Monte Carlo model for simulation of the charge-exchange collisions. The other algorithm simulates the flow of neutral atoms from both sources by use of the direct-simulation Monte Carlo (DSMC) method.

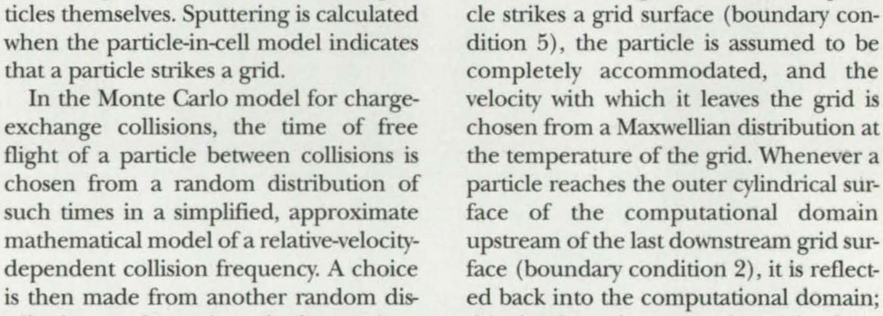
In the charged-particle/particle-in-cell algorithm, each simulation particle carries a representative electric charge and is located in one of the cells of a computational grid. The principal advantage of the particle-in-cell method is that it is based on first principles, with few approximations or *ad hoc* assumptions. The motion of each particle is computed directly from Newton's equations and the equation for Lorentz force. Self-consistent electric and magnetic fields for use in computing the Lorentz forces are computed by use of Maxwell's equations for the electric and magnetic fields generated in part by the motions of the particles themselves. Sputtering is calculated when the particle-in-cell model indicates that a particle strikes a grid.

In the Monte Carlo model for charge-exchange collisions, the time of free flight of a particle between collisions is chosen from a random distribution of such times in a simplified, approximate mathematical model of a relative-velocity-dependent collision frequency. A choice is then made from another random distribution to determine whether a given collision causes charge exchange. In the event of charge exchange, the velocity of the newly created ion is chosen from a random thermal distribution, and thereafter the ion is accelerated according to the charged-particle model.

In the DSMC method used to simulate the flows of neutral gas, the motions of thousands of neutral atoms or molecules are tracked. In this method, one assumes that the gas is so rarefied that the mean free path for collisions between neutral atoms or molecules is much larger than the accelerator grid structure. Thus, collisions between neutral atoms and molecules can be neglected, and the only collisions that must be considered are those between these neutral particles and the grids.

The particles that represent the neutral propellant gas escaping from the discharge chamber are introduced into the computational domain with Maxwellian distributions of velocity at an upstream boundary, as indicated by boundary condition 1 in the figure. Whenever a particle strikes a grid surface (boundary condition 5), the particle is assumed to be completely accommodated, and the velocity with which it leaves the grid is chosen from a Maxwellian distribution at the temperature of the grid. Whenever a particle reaches the outer cylindrical surface of the computational domain upstream of the last downstream grid surface (boundary condition 2), it is reflected back into the computational domain; this simulates the entry of particles from the surrounding region. When a particle reaches the far downstream limit of the computational domain (boundary condition 4) or the cylindrical surface downstream of the last grid surface (boundary condition 3), that particle is removed from the computation. The computation continues until a steady state is achieved.

The flow into the grid structure from the residual gas in the vacuum chamber




The **Computational Domain** for the DSMC calculation is a cylinder, with various boundary conditions at various positions on the upstream and downstream ends, the grids, and the side wall.

is calculated similarly, except that the boundary conditions are different. The calculation of this flow serves to validate the DSMC algorithm, inasmuch as the density of neutral atoms or molecules in the steady state must become approximately uniform at the density of the residual gas in the vacuum chamber. The densities of neutral atoms or molecules obtained from the two Monte Carlo calculations are summed, and the sum is used as the neutral-particle density for the charge-exchange and sputtering calculations.

Predictions made by this computer code were compared with measurements taken in experiments on ion thrusters with several different three-grid configurations. The code predicted the differences among the purveyances of these configurations. It predicted the insensitivity of the current impinging on the accelerator grid to the pressure of the residual gas, but predicted too small a value for this current. The code also predicted the dependence of the decelerator-grid current on pressure and the fact that significant erosion can be caused by ions extracted from a weakly ionized downstream plasma.

*This work was done by Quan Zhang, Xiaohang Peng, and Dennis Keefer of ERC, Inc., for* **NASA's Jet Propulsion Laboratory**. *For further information, write in 72 on the TSP Request Card. NPO-30017*

# Galvanic Cell for Measuring Rates of Corrosion

*Marshall Space Flight Center, Alabama*

A galvanic cell can serve as a simple apparatus for measuring rates of galvanic corrosion of dissimilar metals. Such a cell can be constructed by filling a glass beaker with an electrolyte like that encountered in the corrosive environment, (e.g., 0.1 M NaCl representing a coastal environment), partly immersing coupons of the two dissimilar metals in the solution, attaching wires to the dry parts of the coupons, and connecting the free ends of the wires to the terminals of an ammeter. The galvanic current indicated by the ammeter is directly related to the rate of corrosion.

*This work was done by S. Rachel Khoshbin, John R. Emmons, and Martin W. Kendig of Boeing North American, Inc., for* **Marshall Space Flight Center**. *For further information, write in 54 on the TSP Request Card. MFS-30103*

# Miniature Boundary-Layer Airfoil With Embedded Hot Wires

**Flow could be measured on and very close to surfaces.**

*Lewis Research Center, Cleveland, Ohio*

A miniature instrument has been proposed for measuring flow on and near a surface of interest. Called a "micro hot wire chip," the instrument would be based on the established concept of hot-wire anemometry and would be fabricated by techniques used to make computer chips.

The instrument (see figure) would include an airfoil that would protrude from the surface of interest and that would contain multiple hot-wire anemometers. By providing data on the flow near the surface, the instrument would contribute to understanding of turbulence and other complex flow phenomena. Such understanding may eventually make it possible to reduce skin friction in a variety of machines ranging from aircraft to watercraft such as submarines.

At its base, the airfoil would be integral with a block mounted flush with the surface of interest. The airfoil and block would be made of a thermally insulating material to reduce calibration and wall-proximity errors. Except at the leading and trailing edges, the airfoil would be configured with constant thickness so that the velocity in the midlength region on each side would be constant and equal to the velocity upstream from the airfoil. The hot wires would have rectangular cross sections and would be embedded at the surface of the airfoil at various distances from the surface of interest. One or more wire(s) could also be embedded in the base block for measuring the slip velocity at the surface of interest.

Other instruments (including hot-wire anemometers) for measuring flow velocities near surfaces are available, but none is capable of measuring closer than about 0.02 in. (about 0.5 mm) from the surface. In the proposed instrument, the wires would be only about 0.0002 in. (about 5 µm) thick and one of them could be positioned just above the surface of interest. Thus, the proposed instrument would yield data on flows down to 1/100 of the previous lower limit on distance from the surface.

*This work was done by Danny P. Hwang of* **Lewis Research Center**. *For further information, write in 96 on the TSP Request Card.*

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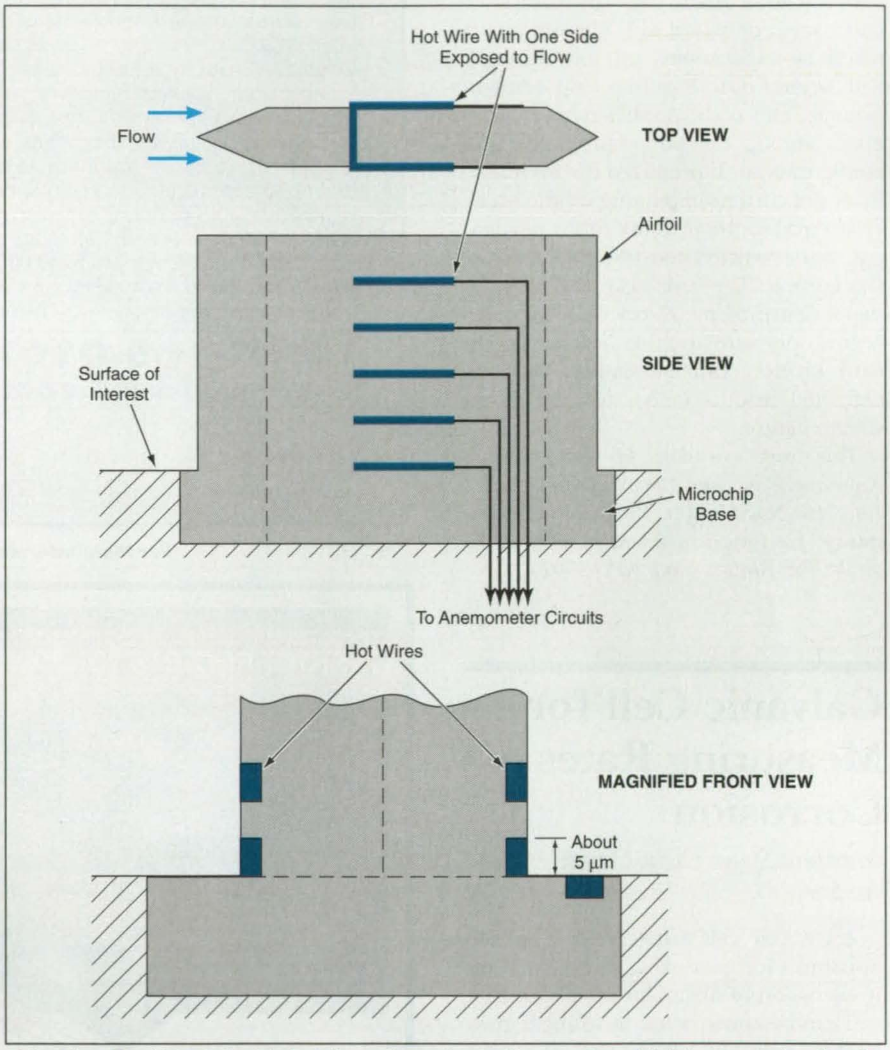



**Thin Wires Would Be Embedded** at the surface of a small protruding airfoil for measuring flow by the hot-wire-anemometer principle at various distances from a surface of interest.

# High-Pressure, High-Temperature Oxygen DTA/TGA System

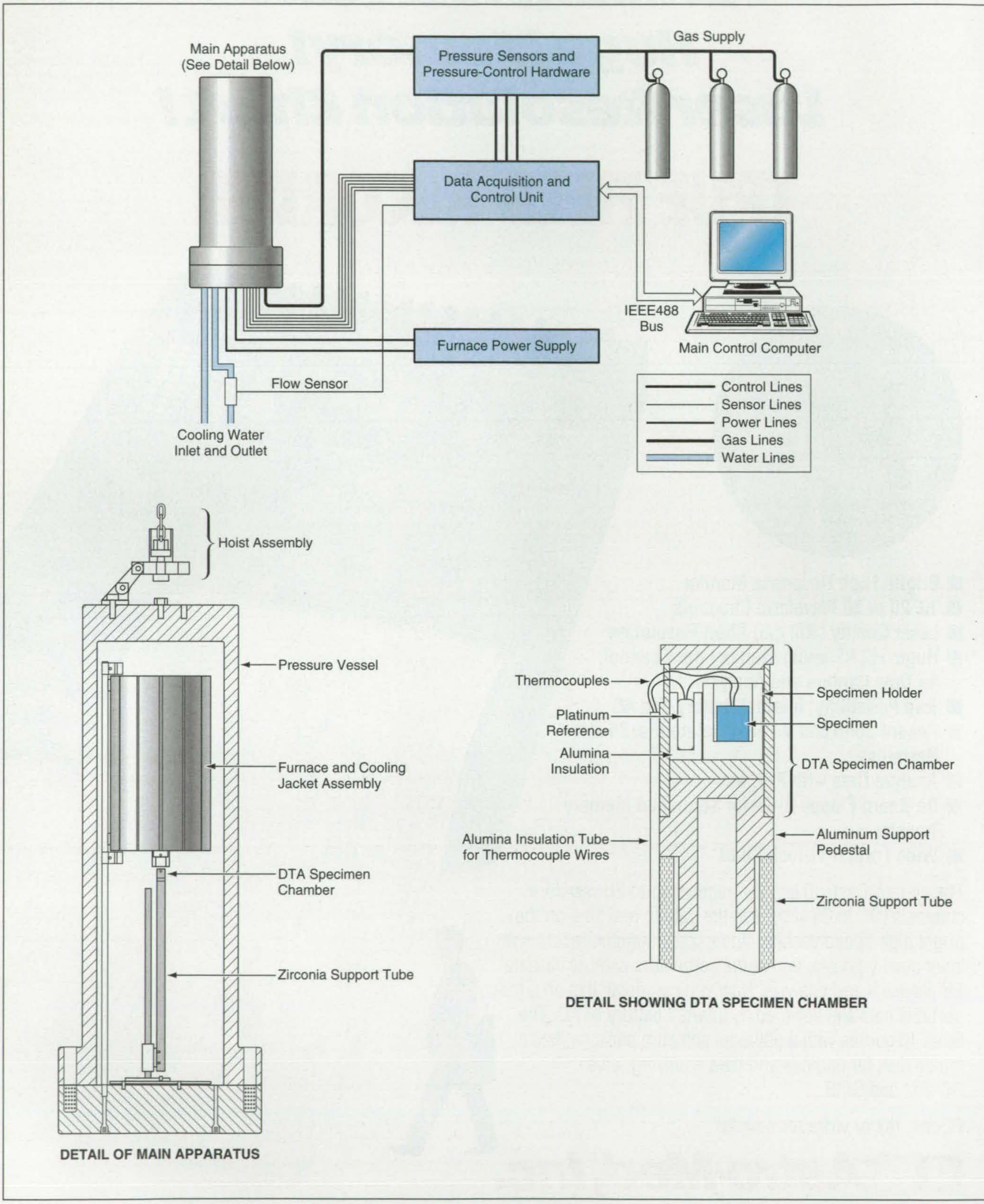
**This system was designed for safely evaluating materials for resistance to ignition and combustion.**

*Marshall Space Flight Center, Alabama*

The figure illustrates a laboratory system for performing differential thermal analysis (DTA) and thermogravimetric analysis (TGA) of specimens of materials at high temperatures in high-pressure oxygen. The system was designed for evaluating the resistance to oxidation and combustion of both metals and nonmetals that might be used in oxygen-handling equipment. Specimen parameters that can be determined by use of this system include ignition and combustion temperatures, temperatures at the onset of major and/or catastrophic

oxidation, and thermochemical activation energies that can be used in calculating rates of oxidation. The system can also be used to determine the fundamental parameters of chemical reactivity of material specimens with gases other than oxygen, as long as those gases are compatible with the internal system materials.

The system includes a main apparatus, which is a stainless-steel pressure vessel that contains an electric furnace for heating the specimen to the test temperature in the oxygen or other test atmosphere at the test pressure. The system also includes a gas-supply subsystem with pressure-sensing and -controlling equipment, a data-acquisition and system-control unit, a computer, a furnace power supply, and plumbing for cooling water.




This **High-Temperature, High-Pressure DTA/TGA System** produces data that can be used to rank materials with respect to ability to resist ignition and combustion in a high-pressure oxygen atmosphere.

The specimen is contained in a DTA or TGA assembly within the main apparatus. These two assemblies are interchangeable with respect to mounting in the main apparatus. Each assembly comprises a DTA or TGA specimen chamber on top of a zirconia support tube on an adjustable-height platform. The specimen chambers are made of alumina, which was chosen for its stability, chemical inertness, and low electrical conductivity at high temperatures in oxidizing atmospheres.

The DTA assembly contains four Pt/(Pt/10 percent Rh) (type-S) thermocouples, which measure the furnace-control, furnace-monitor, specimen, and reference temperatures. The specimen and reference thermocouples are connected in a differential arrangement that yields an additional temperature-related difference between the specimen- and reference-thermocouple voltages. The TGA assembly (not shown in the figure) includes a microbalance, small pressure-resistant chambers for a servo photocell and source of light, a specimen-mounting subassembly, a counterbalance subassembly, a tare subassembly, and a balance stand.

The system has the following unique features:

- It yields useful readings at temperatures up to 1,500 °C (about 1,800 K) and pressures up to 34.5 MPa in both the DTA and TGA modes.
- The position and dimensions of the furnace are chosen to maximize the working space available for the TGA or DTA assembly and minimize the convection of heated gas. This minimization of convection (especially at high temperature and pressure) is essential for TGA.
- The electrical and mechanical subsystems and the computer hardware and software are fully accessible, so that the user can perform adjustments for special situations.
- The system operates safely, even though it contains oxygen at high temperature and pressure.
- Ignition, combustion, and onset-of-oxidation temperatures can be measured to within approximately 1.6 °C

*This work was done by James W. Bransford of James W. Bransford & Associates for* **Marshall Space Flight Center**. *For further information, write in 44 on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26419.*

# Growing Small-Diameter, Single-Crystal Oxide Fibers

## $Y_3Al_5O_{12}$ fibers may be useful as high-temperature reinforcements in composite materials.

*Lewis Research Center, Cleveland, Ohio*

Small-diameter, single-crystal fibers of $Y_3Al_5O_{12}$ (yttrium aluminum garnet, often abbreviated as "YAG") have been grown in an improved edge-defined, film-fed (EFG) growth process. YAG and other yttria alumina compounds have been considered for use in metal- and ceramic-matrix composite materials; because YAG resists creep at high temperatures, YAG fibers may be useful as high-temperature reinforcements of ceramic matrices.

Figure 1 illustrates the basic EFG process. A fiber is grown by cooling and thereby solidifying molten fiber material while pulling the material (in this case, molten sapphire) upward from the horizontal annular top surface of a vertical cylindrical die. Normally, the molten material wets the top of the die, and the outer diameter of the die and the fiber grows slightly narrower than this diameter. The molten material flows from a crucible below, through a capillary passage in the die to the orifice at the top of the die.

The surfaces of the top of the die and the capillary passage are made from a material that is compatible with the liquid and solid phases of the fiber material and is wetted by the molten fiber material. The capillary passage is extended into the molten material in the crucible and is dimensioned so that surface tension in the molten material is sufficient to provide the capillary action needed to feed the molten material to the top of the die.

Growth is started by causing the molten material on top of the die to solidify on a seed fiber, then starting to pull the seed fiber upward at a speed consistent with the rate at which molten material can be supplied to maintain the film and/or the rate at which heat liberated by solidification can be rejected. Proper adjustment of the temperature of the melt and the pulling speed makes it possible to grow a crystalline fiber continuously.

The present EFG process incorporates two improvements (see Figure 2). One of the improvements is a combination of (1) an increase in the pulling speed and (2) modification of the top surface of the die to decrease the tendency toward wetting. These changes affect the balance of hydrostatic and capillary forces in such a way as to enable growth to occur in the inside-edge-defined, self-filling (IESF) mode, in which the melt retracts to the orifice and the diameter of the fiber is governed by the inside edge of the die instead of the outside edge as before (see Figure 2). IESF growth is started in the same way as before, but as the pulling speed is increased, the shape of the meniscus changes and at a critical speed, the melt suddenly narrows to the diameter of the orifice. The advantage of IESF mode is that small-diameter fibers can be grown more easily while still using wide, robust dies.

The other improvement lies in the design of guides to help maintain the desired crystallographic orientation of the fiber, and to keep the fiber straight and centered on the centerline of the die. Traditionally, a rigid guide has been mounted on the furnace above the die. Given thermal expansion of the die and dimensional tolerances of mating parts, it is difficult to maintain the necessary precise orientation of the guide with respect to the die. In addition, if the guide fits too tightly about the growing fiber, such minor defects as small kinks in the fiber can jam at the guide, stopping growth. The improved design combines a precise guide mounted integrally with the die lid and a loosely fitting guide mounted on the furnace in which the crucible is located.

*This work was done by Winfield B. Perry and Richard C. Ventura of Advanced Crystal Products Corp. and Ali Sayir of Case Western Reserve University for* **Lewis Research Center**. *No further documentation is available.*

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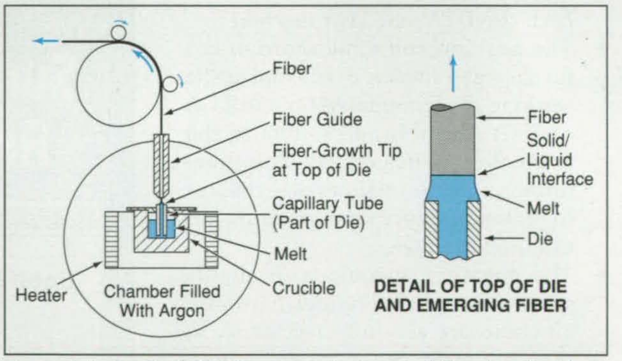



Figure 1. In the **Basic EFG Process,** a single-crystal fiber is pulled from a melt. The diameter of the fiber is governed by the outer diameter of the die, the top of which is wetted by the molten fiber material.

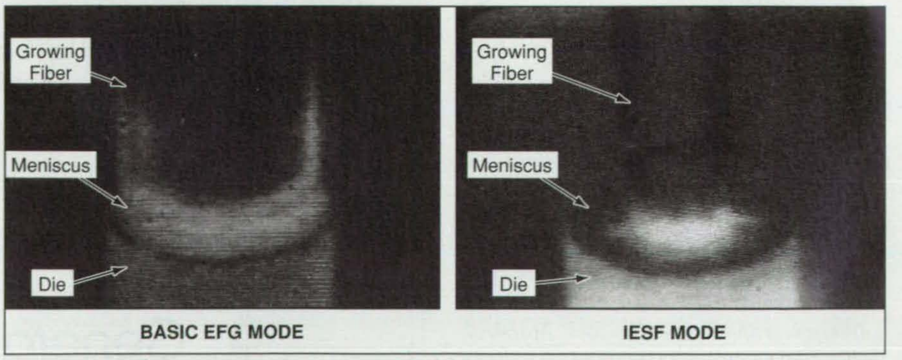



Figure 2. **YAG Fibers** are shown here growing in the basic EFG and the IESF modes from a die with an outer diameter of 250 μm and an inner diameter of 75 μm. In the IESF mode, the melt retracts to the orifice, so that the diameter of the growing fiber is governed by the inner diameter of the die.

# $Si_3N_4$-Based Fiber-Coating Material for Ceramic Composites

**This material imparts graceful degradation and resistance to high-temperature oxidation.**

*Lewis Research Center, Cleveland, Ohio*

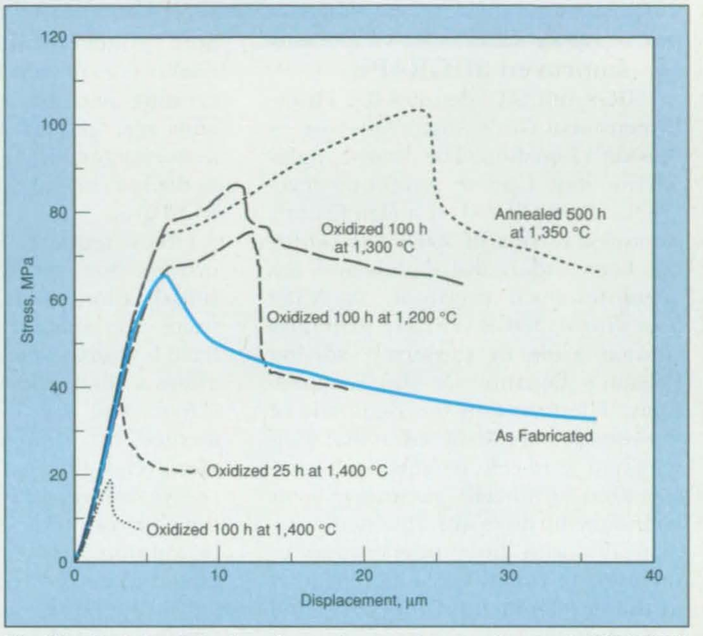
A $Si_3N_4$-based coating material and coating process have been developed to provide improved interfacial layers between SiC fibers and the SiC fiber or $Si_3N_4$-matrix of composite materials. SiC/SiC and SiC/$Si_3N_4$ composites are candidates for use in high-temperature turbines. Typically, ceramic composites of this type have been made with C- and BN-based fiber-coating materials, which have limited oxidation resistance. Experiments have shown SiC/$Si_3N_4$ composites made with this improved $Si_3N_4$-based fiber-coating material exhibit very good (good in terms of the "graceful failure" explained below) interfacial behavior as determined in fiber-push-out tests, in both the as-fabricated condition and after annealing and oxidation exposure.

In the context of a ceramic or other brittle composite material, "graceful failure" denotes a failure mode in which fibers debond from the matrix. This failure mode is desirable for limiting damage. The fiber-coating materials that are incorporated into nonoxide ceramic-matrix composites are weak interfacial materials that are used to promote graceful failure. The C- and BN-based fiber-coating materials mentioned above have not performed well because they become oxidized easily and in a way that can impair the long-term performance of the composites that contain them.

This improved $Si_3N_4$-based coating material is a silica former; when the interfacial layers are fully formed, they are porous mixtures that consist largely of $Si_3N_4$ and $SiO_2$. As a class, silica formers exhibit excellent resistance to oxidation, and are among the most promising candidates to succeed interfacial C and BN. When made with a high volume fraction of suitably dispersed pores, the $Si_3N_4$-based interfacial layers can perform the interfacial function of limiting damage through diversion of cracks. Porosity reduces the shear strength of brittle solids. Thus, a porous, brittle interfacial material in a ceramic-matrix composite is likely to constitute a preferred path for the diversion of cracks propagating from the matrix; this would promote debonding of fibers and thus graceful failure of the composite.

More specifically, the improved interfacial material contains $Si_3N_4$ bonded with silica, and with tailored porosity generated by the pyrolysis of organic microspheres. In the fiber-coating process, the precursor mixture destined to become the interfacial material is applied as a slurry coating on SiC fibers. The coating is then consolidated in slow calcination and annealing treatments.

Small composite specimens for use in the experiments were made with reaction-bonded silicon nitride (RBSN) as the matrix material, Textron SCS-0 (chemical-vapor-deposited SiC) as the fiber material, and the improved interfacial coating material. In the fiber-push-out tests, the mean fiber-debonding and sliding stresses of the specimens in the as-fabricated condition were ≈60 and 50 MPa, respectively. This performance can be compared with the current benchmark interfacial performances of (a) a debonding stress of 10 MPa characteristic of a composite that is similar except that the fiber material is SiC with a C-based coating (an SCS-6-fiber/RBSN-matrix composite) and (b) lack of push-out in another composite that is similar except that there is no interfacial material (an SCS-0-fiber/RBSN-matrix composite).




The **Fiber-Push-Out Behavior**, after various treatments, of a sample SCS-0/RBSN minicomposite with porous interphase is shown.

In the specimens containing the porous $Si_3N_4$/$SiO_2$ interfacial material, fiber-push-out was still achieved after two severe durability tests involving exposure to high temperatures. In one of these tests, the specimens were subjected to prolonged annealing in $N_2$ at a temperature of 1,350 °C to induce coarsening of the microstructure and promote bonding of the interfacial material to the fiber and matrix materials through sintering. In the other test, 1.0-mm-thick wafer specimens were oxidized for times from 25 to 100 hours, at temperatures from 1,200 to 1,400 °C. These were intended as accelerated tests to simulate what might happen to the interfacial layers in service.

In unnotched samples of the minicomposite (as-fabricated, annealed, or oxidized) tested to fracture in bending, the crack path was observed to pass through the porous interphase in all cases. In control samples of SCS-0/RBSN and SCS-6/RBSN oxidized for 50 h and similarly tested in bending, fracture included the fiber in places. The results of the fiber push-out tests are shown in the figure. The interfacial performance was not impaired by the high-temperature exposures: the stresses needed for debonding and sliding remained in the range of 80 ± 20 MPa typically observed for SiC/SiC composites with a BN interphase. Accordingly, the porous $SI_3N_4$/$SiO_2$ interphase is considered to resist oxidation, and the composite that contains this interphase is considered to survive oxidation. Efforts to apply this material to small-diameter fibers in tows and weaves are underway.

*This work was done by Linus U. J. Thomas-Ogbuji of NYMA, Inc., for* **Lewis Research Center**. *No further documentation is available.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Rd., Cleveland, OH 44135. Refer to LEW-16261.*

# Computer Software

## Improved 3DGRAPE

"3DGRAPE/AL" denotes the Three-Dimensional Grids About Anything by Poisson's Equation/The Ames-Langley Technology Update computer program. 3DGRAPE/AL is a significantly improved version of 3DGRAPE, which has been widely distributed and has been described previously in *NASA Tech Briefs*. 3DGRAPE/AL generates volume grids by iteratively solving Poisson's Equation in three dimensions. The terms on the right side of the equation are designed so that user-specified grid-cell heights and user-specified grid-cell skewness near boundary surfaces are obtained automatically, with little intervention by the user. Versatility was a high priority in the development of this code, and as a result, the code can generate grids in almost any three-dimensional physical domain. 3DGRAPE/AL can be run in batch mode like the original 3DGRAPE, and it offers a graphical user interface (GUI) on Silicon Graphics, Inc. (SGI) computers.

3DGRAPE/AL reads in predefined data, generates a grid, and writes it out. For those boundary surfaces which are of interest ("the body"), it expects to read X,Y,Z coordinates of surface grid points that the user has defined previously by use of other software. Other boundary surfaces of less interest ("the outer boundary") can be found by the program itself, using simple analytic shapes. The grid can consist of multiple blocks, and the program is capable of finding its own internal block-to-block boundary surfaces.

3DGRAPE/AL offers a significant number of features that were not offered by 3DGRAPE. In 3DGRAPE/AL, grid quality is enhanced by reformulated control terms in Poisson's Equation. The user can specify arbitrary angles with which lines are to intersect boundaries; that is, these angles are no longer limited to the single value of 90° everywhere. Better grid quality results from the addition of Thomas & Middlecoff (T&M) clustering terms for cases in which all six faces of a block are read in. The user can choose terms of either the Steger & Sorenson or the T&M type, or a blend between the two types that gives good cell size and skewness control at both boundaries and the interior. Grid quality is evaluated by computing and printing maxima, minima, medians, and averages of cell heights and nonorthogonality, at boundaries and in the interiors of the blocks of the finished grid.

Other features in 3DGRAPE/AL provide for speedier convergence. Initialization is improved by transfinite interpolation (for cases with six fixed boundary surfaces), which either offers a final grid or speeds convergence. The use of Erlich's ad hoc method for computing locally optimum relaxation parameters for a successive-over-relaxation (SOR) solver in the code can also speed convergence. In addition, convergence can be accelerated when the code is vectorized in any of the three coordinate directions (when installed on Cray computers), allowing the longest possible vector length in each block. These features, combined with careful code optimization, result in a speedup over the previous code by approximately a factor of four.

Various other features that assist in the input of data are also offered by 3DGRAPE/AL. These features include two input filters: (1) an input filter that accepts GRIDGEN (ARC-13371) output as input and converts it to 3DGRAPE/AL input and (2) an input filter that reads input designed for the original 3DGRAPE and reformats it for use with 3DGRAPE/AL. For more versatile input, required cell heights and skewness at read-in surfaces can be specified by the user at each point from a file, a complete grid generated elsewhere can be read in, and an elliptic solver in 3DGRAPE/AL can be run a few steps to smooth the grid. More extensive error checking of input data has been implemented, and a GUI (for SGI computers) enables the user to watch selected grid surfaces while the grid solver in 3DGRAPE is iterating. The GUI also enables the user to suspend the iterative process and plot convergence histories.

3DGRAPE/AL is written in FORTRAN 77 for UNIX-based computers. The graphical mode of 3DGRAPE/AL makes use of the Iris Graphics Library (IGL) and is written in FORTRAN 77 for SGI IRIX machines. An ANSI standard FORTRAN compiler is required to build executable codes. Sample input and output are included on the distribution medium. The batch mode of 3DGRAPE/AL has been successfully implemented on the following computers: an SGI Indigo2 running IRIX 5.2, a Sun4 running SunOS 4.1.3, a Sun4 running Solaris 2.4, an IBM RS/6000 running AIX 4, an HP 9000/720 running HP-UX 9.03, and a Cray Y-MP running UNICOS 8.0.3.4. The graphical mode of 3DGRAPE/AL has been successfully implemented on an SGI Indigo2 running IRIX 5.2. The standard distribution medium for 3DGRAPE/AL is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (Sun QIC-24) in UNIX tar format. Alternative distribution media and formats are available upon request. An electronic copy of the documentation in PostScript format is included on the distribution media. 3DGRAPE/AL was released to COSMIC in 1996.

*This program was written by Reese L. Sorenson for* **Ames Research Center**. *For further information,* ***write in 27*** *on the TSP Request Card.*
*ARC-14069*

## Software for Efficient Packing of Cargo

The Stowage Tactics for User Flights (STUF) computer program enables space-station users to develop schemes for efficient packing of their cargo. Users determine which trays to use and where those trays are located in a stowage rack. Locations of cargo items in a tray can be determined by computer, or a user can place items as desired. The weight and center of gravity of each item are monitored. Any out-of-bounds condition for a packed tray or rack is highlighted for corrective action. STUF can also combine many users' packing schemes into one cargo manifest; this enables a NASA Center to integrate all user stowage for a space-station mission.

After a file representing user cargo data is read by STUF, cargo is tentatively assigned to a stowage tray and checked for interference with items already assigned to the tray. Any items that do not fit the current tray are assigned to subsequent trays, if possible. Once all trays are loaded, the user determines the location of each tray in

a space-station rack. The analytical results returned by STUF become inputs to a broader space-station cargo manifest.

The user interface for STUF is primarily menu-driven. STUF provides two operational modes for tray packing: automatic and interactive. The interactive mode is the quickest to use when packing hundreds of items, and it results in the best packing efficiency. The automatic mode enables the computer to determine where each cargo item is to be placed. A single tray size selected by the user is then used repeatedly for all trays.

Once a set of trays has been packed, the user may wish to place those trays into space-station racks. Stowage racks contain locker assemblies specifically designed to hold certain tray sizes. Although STUF allows a user to determine where a tray is located within the rack, STUF will not place the tray there if the location cannot accommodate it. If a tray-packing solution is later edited, STUF automatically updates mass properties for the rack that contains that tray.

STUF can accommodate 9,999,999 cargo items, 999 trays, and 99 racks per packing operation. Packing foam must be accounted for as part of each cargo item. STUF does not add the properties of foam to the mass properties of any item.

STUF is written to run with DesignCAD 3-D and is available only as object code for IBM PC-compatible computers. It has been successfully implemented on a 486 DX2 computer under MS-DOS 5.0. STUF requires DesignCAD 3-D v4.0, 640K of random-access memory, a graphics display, and a hard disk drive. A printer is highly desirable for capturing STUF output. The standard distribution medium for STUF is one 3.5-in. (8.89-cm), 1.44MB, MS-DOS-format diskette. An electronic copy of the documentation in ASCII format is included on the distribution medium. STUF was released to COSMIC in 1996 and is a copyrighted work with all copyright vested in NASA.

*This program was written by Vance Houston of* **Marshall Space Flight Center**. *For further information,* ***write in 29*** *on the TSP Request Card.*
*MFS-31101*

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# Gripper for Testing Composite-Material Tubes

## Special preparation of ends of tubes is unnecessary.

*Lewis Research Center, Cleveland, Ohio*

A tool has been designed to grip an end of a tubular specimen of composite (matrix/fiber) material for mechanical testing, without crushing or unduly deforming the gripped portion of the specimen. The tool makes it unnecessary to fabricate the ends of specimens to complex shapes for gripping, as has been common practice until now. The tool simplifies and reduces the cost of mechanical tests to measure torsion and tension properties of tubes made of metal-matrix composites for material characterization and for such applications as torsion bars and drive shafts.

The tool (see figure) is essentially a combination of a mandrel and a collet. The mandrel comprises three sectors of a cylinder with a conical inner surface that mates with a conically tapered inner plug. The mandrel is inserted in the tube and, by use of the tapered plug, is expanded gently into contact with the inner surface of the tube.

The collets are installed into a commercially available hydraulic gripping device used in materials testing, and remain there throughout the test program. The tube-and-mandrel assembly is then inserted into the collets, and hydraulic pressure is applied to circumferentially grip the specimen. The test can then proceed.

*This work was done by Christopher S. Burke of NYMA, Inc., for* **Lewis Research Center**. *For further information, write in 89 on the TSP Request Card.*

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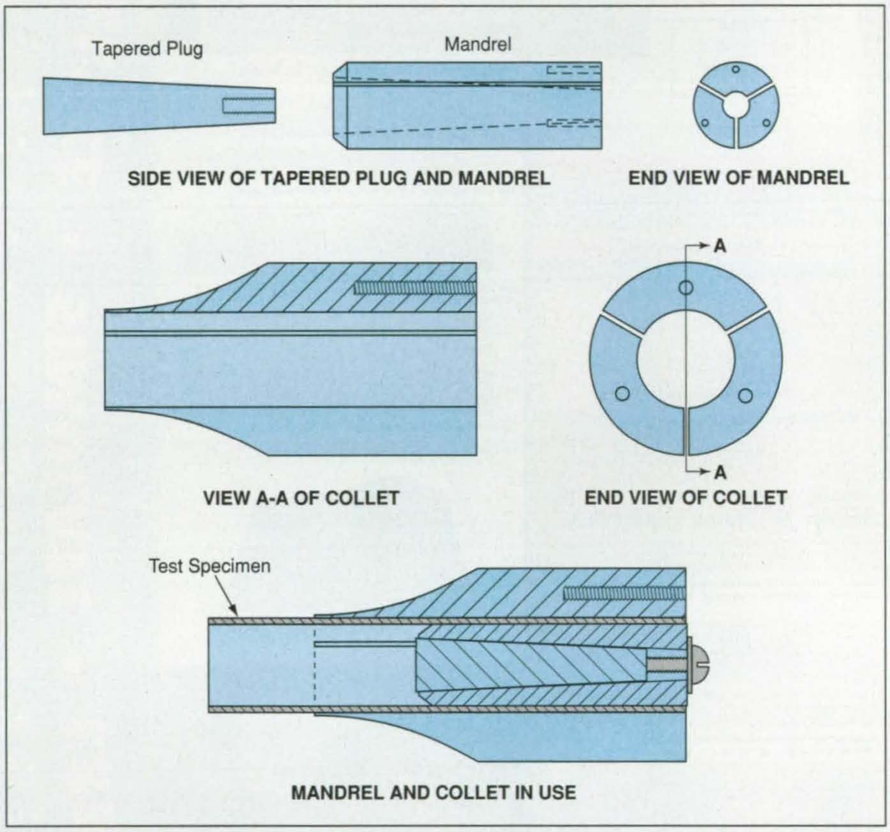


The **Mandrel Radially Supports** the tube against the radially inward gripping force applied by the collet, thereby preventing crushing of the tube.

# Screens Would Suppress Flow-Induced Resonances in Cavities

## The key is to choose proper spacing of holes.

*Ames Research Center, Moffett Field, California*

Aeroacoustic resonances in shallow cavities exposed to subsonic airflows would be suppressed, according to a proposal, by partly screening the cavity apertures with perforated thin metal sheets. (As used here, "shallow cavities" denotes cavities that are longer than they are deep.) It is desirable to suppress flow-induced pressure fluctuations associated with aeroacoustic resonances where they could interfere with equipment mounted in the cavities; such equipment could include heat exchangers, weapons on aircraft, acoustic sensors, sound absorbers, and chemical-analysis instruments, for example.

For a given screened cavity, aeroacoustic resonances occur because of coupling between aerodynamic excitation on the screen and acoustic pressure fluctuations in the cavity. More specifically, aeroacoustic resonances occur because of coupling between (1) oscillations of flow into and out of the cavity, associated with shedding of vortices from the holes (see Figure 1); and (2) pressure fluctuations associated with


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acoustic resonances of the screened cavity. Indeed, the frequency of shedding of vortices tends to lock to the nearest cavity modal frequency.

The frequency of shedding of vortices is given by $f_V = S_t U_0/d$, where $S_t$ is the Strouhal number, $U_0$ is the average airspeed, and $d$ is the diameter of a hole. If the diameter is specified in millimeters, then the Strouhal number is given by $S_t = m(0.10d - 0.01)$, where $m$ is a positive integer that corresponds to the harmonic of the fundamental shedding frequency.

The tendency toward the coupling that causes aeroacoustic resonances can be expressed in terms of a phase-coupling parameter given by $\lambda_V/l = U_C/(f_V l)$, where $\lambda_V$ is the vortex-sheet wavelength (that is, the streamwise distance between vortices), $l$ is the distance between holes, and $U_C$ is the speed of convection of the vortices. Wind-tunnel tests have shown that the aeroacoustic resonances occur when the phase coupling parameter has a value of 1/4, 1/2, or 1.

Substituting the expression for $f_V$ into the equation for the phase coupling parameter, one obtains

$$\lambda_V/l = U_C d[U_0 l m(0.10d - 0.01)]$$

Thus, the phase coupling parameter depends only on the perforation geometry and on $U_C/U_0$. In general, $U_C/U_0$ lies between 0.5 and 0.75, and is probably constant over a wide range of airspeeds. This suggests that it should be possible to choose the perforation geometry (that is, to choose $d$ and $l$) to set the phase coupling parameter at a value other than 1/4, 1/2, or 1 to suppress aeroacoustic resonances.

Practical values of $d$ lie between 1.5 and 3 mm. Preferably, $d$ should be chosen toward the low end of this range; as the holes are made smaller, the flow into and out of the cavity becomes increasingly affected by viscous damping at the edge of the hole, so that resonances become weaker.

Suppose, for example, that one chooses $d$ = 1.59 mm and $l$ = 5.16 mm. This results in $U_C/U_0 \approx 0.58$, and the resulting value of the phase coupling parameter is approximately 1.2, 0.6, or 0.4 for $m$ = 1, 2, or 3, respectively. These values differ significantly from the resonance values so that, in principle, the resonances should be suppressed. In an experiment to test this concept, a screen with these dimensions was placed over a cavity 302 mm deep. Another cavity of equal depth was covered with a screen of $d$ = 3.18 mm and $l$ = 12.70 mm to obtain a phase coupling parameter of 0.5, which is a resonance value. The results of the experiment indicated that the resonance was much weaker in the cavity covered by the $d$ = 1.59 mm, $l$ = 5.16 mm screen, as expected.

*This work was done by Paul T. Soderman of* **Ames Research Center**. *For further information, **write in 86** on the TSP Request Card.*
ARC-13213

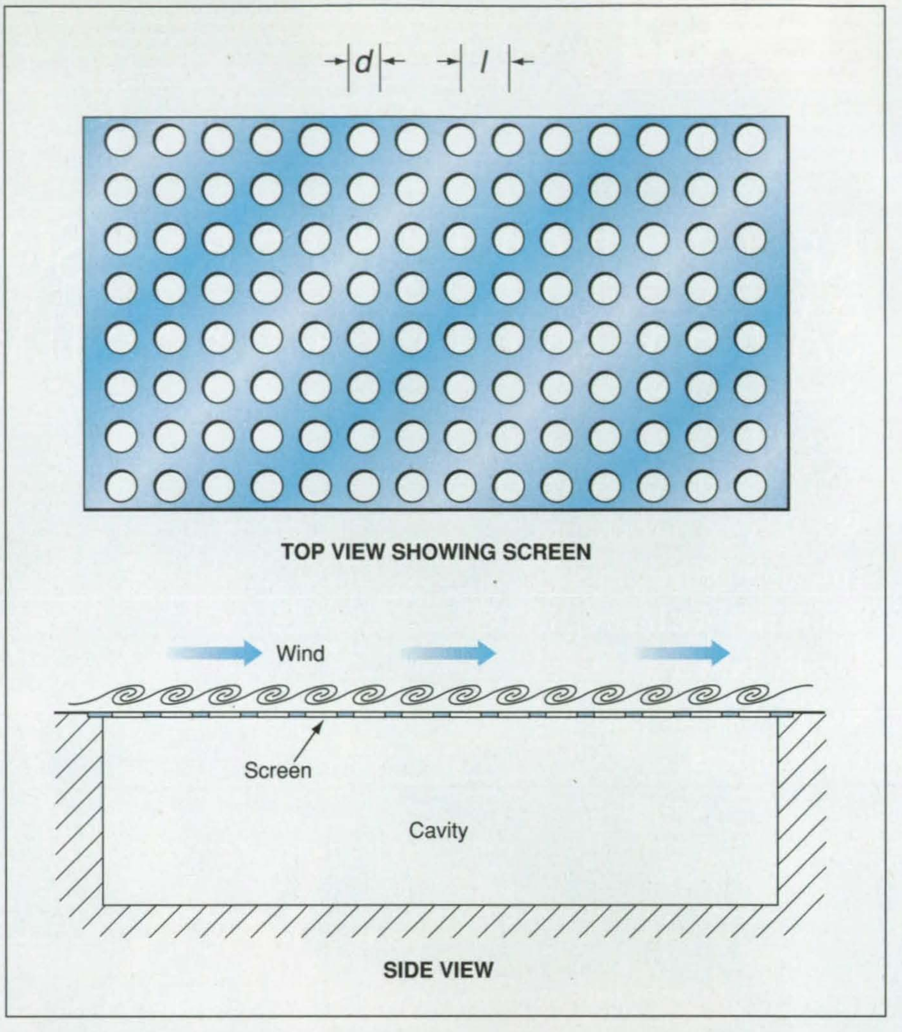



Figure 1. The **Perforated Metal Sheet Sheds Vortices** as air flows past the cavity, exciting acoustic resonances in the cavity.

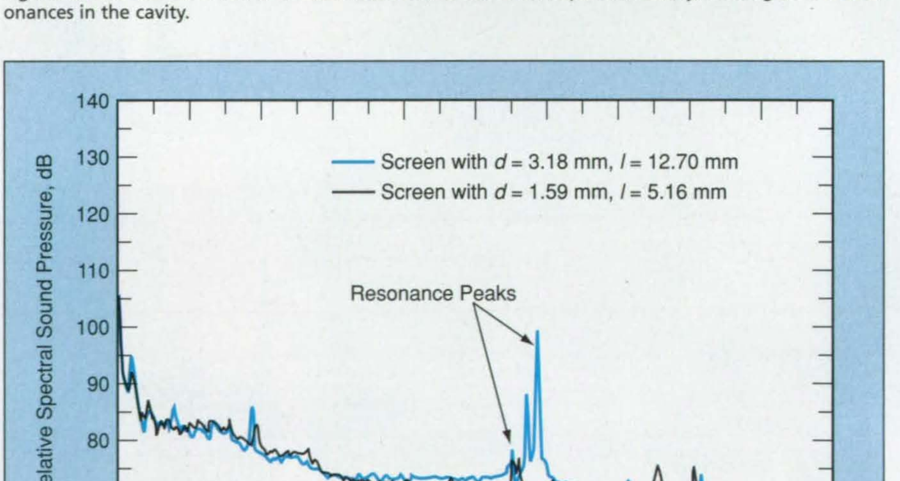



Figure 2. The **Peaks in the Spectrum of Sound** excited by air flowing past the cavity are reduced sharply by choosing $l$ and $d$ to avoid aeroacoustic resonances.

# Liquid-Vaporizing Microthrusters

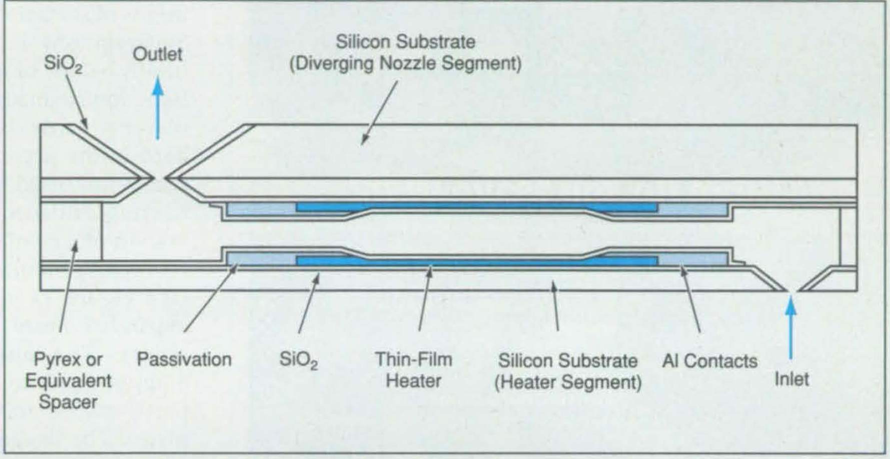
## Liquid propellant would substantially reduce or eliminate containment and leakage problems.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A development of liquid-vaporizing microthrusters is proposed for spacecraft with masses of no more than 10 kg. In a typical application, a propellant liquid (e.g., water, ammonia, or hydrazine) would be stored in the liquid phase. When thrust was needed, some of the liquid would be fed to a microthruster, wherein the liquid would be heated, vaporized, and expanded through a nozzle to produce thrust. The microthruster would be micromachined from silicon and would weigh only a few grams. The microthruster assembly would be made to fit on a chip typically 1 $cm^2$. One of the principal advantages of using a liquid propellant (in contradistinction to a gaseous propellant) is that a liquid propellant could be contained much more easily, presenting less of a leakage problem.

A typical microthruster (see figure) would feature a layered structure with silicon dioxide films (for thermal insulation) on silicon substrates, thin-film electrical heaters made of polysilicon, gold electrical contacts, and passivation layers of silicon nitride covering all surfaces in contact with the flow.

*This work was done by Juergen Mueller, Stephanie Leifer, Lilac Muller, and Thomas George of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, write in 11 on the TSP Request Card. NPO-19928*




A **Liquid-Vaporizing Microthruster Concept** would be based on a layered structure using thin-film electrical heaters to vaporize liquid propellants.

# Technique for Calibration of a Shearographic Instrument

## Shearograms are taken on a cantilever beam.

*Marshall Space Flight Center, Alabama*

A technique for calibration of an optoelectronic shearographic instrument is based on the use of a cantilever beam with a concentrated end load as a standard for elastic deformation of a test object under mechanical stress. Deformations of a test object under mechanical stress can include displacements of surfaces in directions perpendicular to the surfaces. Shearography is a noncontact optical method (explained briefly below) of measuring such displacements along lines of sight approximately perpendicular to the surfaces. A cantilever is particularly suitable as the elastic-deformation standard in the present technique because cantilever beams are commonly used to teach stress-vs.-strain relations to engineering students, and the basic equations for elastic deformation of a cantilever beam are well established.

A representative optoelectronic shearographic instrument (see Figure 1) includes a laser and optics that provide an expanded beam of coherent light to illuminate the test object. The instrument also includes a video camera equipped with an image-shearing lens, which is a lens covered partly with a wedge-shaped prism (or with a birefringent plate). The image-shearing lens produces two closely related effects; each point on the test object is imaged at two points on the focal plane of the camera, and each point on the focal plane of the camera receives light from two points on the test object. The distance ($\delta x$) between the points on the test object is called the "shear distance" and is easily measurable on the test object.

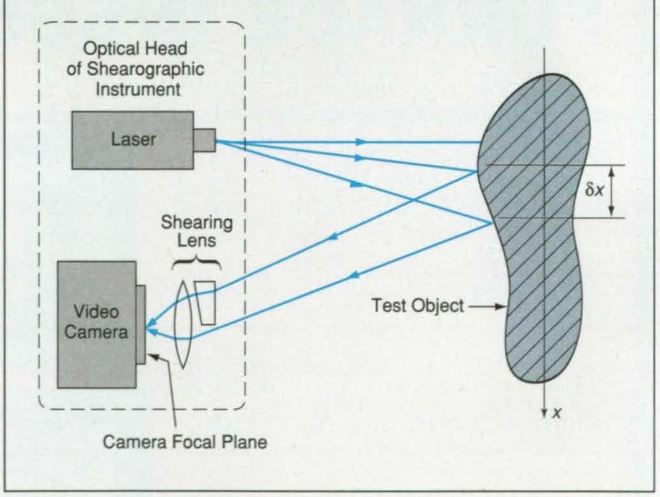



Figure 1. A **Shearographic Instrument** exploits interference between rays of coherent light arriving at one point on the camera focal plane from two different positions on the test object.

Shearography is an interferometric method that relies on the second-mentioned effect of the image-shearing lens. The portions of light arriving at a point on the focal plane of the camera from two points separated by $\delta x$ have two different phases because of the difference between the distances the two portions have traveled from the laser. The phase difference and thus the interference between these two portions depends on the local deviation of the surface of the test

object from a nominal constant-phase surface approximately perpendicular to the line of sight. The overall effect is to produce an image containing interference fringes that correspond to contours of the slope of observed surface of the test object. Typically, one records such a sheargraphic image when the test object is unstressed, then records another image when the object is stressed. From the shift in interference fringes between the stressed and unstressed conditions, one can compute changes in slope and displacement of the observed surface of the test object.

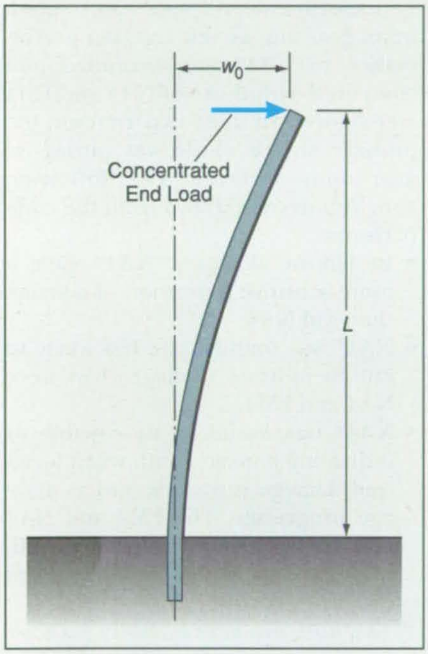



Figure 2. A **Cantilever Beam Subjected to a Known Displacement** by a concentrated end load serves as the test object in the present calibration technique.

In the present technique, the apparatus is set up to observe the slope and displacement of a cantilever beam (see Figure 2). Shearograms are recorded both with the beam undeflected and with the beam under a concentrated end load to obtain a measured end deflection $w_0$. The two main equations used in the present technique are derived from the basic equation for shearographic interference and the basic equation for deformation of a cantilever beam under a concentrated end load. The first equation gives the order, $n$, of the interference fringe at point $x$ along the beam:

$$n = \left(3w_0\delta x/\lambda L^3\right)\left(2Lx - x^2\right)$$

where $w_0$ is the deflection at the end of the beam, $\lambda$ is the laser wavelength, and $L$ is the length of the beam. The second equation gives the calibration error, expressed as the fractional difference, $\xi$, between the observed and predicted values of the slope of the beam at point $x$:

$$\xi = n\lambda L^3/3w_0\delta x\left(2Lx - x^2\right) - 1$$

During a calibration procedure, one determines the position $x$ at which each integer fringe order $n$ occurs on the shearogram, then inserts the values of $n$ and $x$ into the second equation. Thus, a value of fractional error is assigned to each fringe. If the range of slopes to be encountered during subsequent tests is known or can be predicted, then the maximum error observed in that range during calibration can be taken as the maximum error during the subsequent tests.

*This work was done by Samuel S. Russell of* **Marshall Space Flight Center** *and Matthew D. Lansing and Gary L. Workman of the University of Alabama in Huntsville. For further information, write in 42 on the TSP Request Card.*
*MFS-26364*

# Enhancement of the NA4 Gear-Vibration Diagnostic Parameter

**This version of NA4 provides a more sensitive indication of damage.**

*Lewis Research Center, Cleveland, Ohio*

"NA4*" denotes an enhanced version of the NA4 gear-vibration diagnostic parameter, which was described in "Analyzing Vibrations To Detect Damage on Gear Teeth," (LEW-15974), *NASA Tech Briefs*, Vol. 21, No. 2 (February 1997), page 1b. NA4 is one of several time-varying statistical parameters that are computed from measurements of vibration in gear trains to detect damaged gear teeth. Vibration-analyzing systems that compute NA4 and the other parameters are being developed to monitor gear drives to provide timely warnings during operation.

Vibration in a gear train is measured using an accelerometer mounted on the gear housing. The instantaneous output of the accelerometer is recorded digitally. A synchronizing signal is recorded with the vibration signal to allow time-synchronous averaging. Time-synchronous averaging reduces the effect of incoherent noise and improves the signal-to-noise ratio.

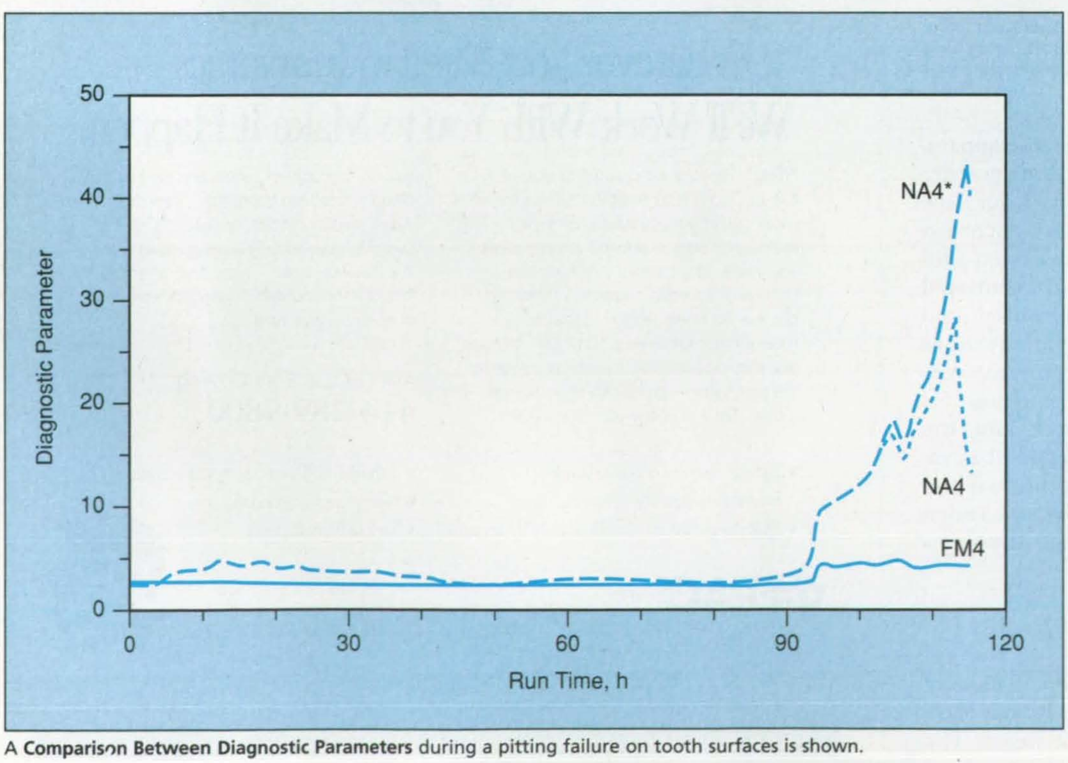
NA4 was developed to overcome some of the limitations of another parameter, called "FM4," that is widely accepted in industry. In preparation for computing NA4, the data are preprocessed into a residual signal by removing certain components synchronous with the meshing of gears while retaining first-order sidebands. NA4 is defined as the normalized fourth statistical moment of the residual signal divided by the square of the current run-time averaged variance of the residual signal. NA4* is similar to NA4 in that its numerator is also the kurtosis of the residual signal. However, the denominator of NA4* is the square of the variance of the undamaged gearbox signal.

The change from NA4 to NA4* allows the parameter to continue to grow with the severity of the fault. NA4* is a parameter that is more robust when damage progresses since the comparison is being made to the gearbox when it was in a good condition. The formulation of NA4* provides for indication of damage both at initiation and as damage progresses. In experiments on spur- and spiral-bevel gear fatigue test rigs, the performance of NA4* was examined and compared with those of NA4 and FM4 (see figure). In these experiments, the primary failure mode was pitting of gear-tooth surfaces. The following conclusions were drawn from the comparisons:

- In almost all cases, NA4* gave a more sensitive indication of damage than did NA4.
- NA4* was found to be less likely to fail to indicate damage than were NA4 and FM4.
- NA4* was found to be capable of indicating damage, both when localized damage is present and as damage progresses. The FM4 and NA4 parameters, however, cannot indicate damage after localized damage has progressed.

*This work was done by Harry J. Decker of the Vehicle Technology Center of the U.S. Army Research Laboratory, James J. Zakrajsek of* **Lewis Research Center**, *and Robert F. Handschuh of the Vehicle Technology Center of the U.S. Army Research Laboratory. For further information* ***write in 65*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16284.*




A **Comparison Between Diagnostic Parameters** during a pitting failure on tooth surfaces is shown.

# Automatic Regulation of Material Level in Industrial Blender

*Marshall Space Flight Center, Alabama*

A control system automatically regulates the level of material in an industrial blender in which maintaining the correct level is necessary for both product quality and safety. The blender includes a mixing chamber with a turbine-type head that mixes two powder streams that enter from the top, with a liquid stream that enters from the bottom. The resulting blend flows out of the chamber through a discharge gate at its bottom. The level-regulating control system includes two level sensors on the side of the chamber, one slightly above the other. The outputs of these sensors are fed to a programmable-logic controller (PLC) that, in turn, controls a linear actuator that varies the opening of the discharge gate. The PLC modulates the gate opening to maintain the material level between the two sensors. A third sensor on the chamber lid provides redundant protection against flooding: if the material level rises to near the lid, the output of this sensor triggers an emergency shutdown of all material feeders.

*This work was done by Joel Crook of Thiokol Corp. for* **Marshall Space Flight Center**. *For further information, **write in 82** on the TSP Request Card.*
*MFS-31127*

# Vibration-Isolation System for Industrial Blender

*Marshall Space Flight Center, Alabama*

A pneumatic suspension system for the industrial blender described in the preceding article suppresses low-frequency vibrations generated by the motor that drives the blender. It is necessary to suppress these vibrations because they can affect feed rates of the materials to be mixed and thereby alter the composition of the blend beyond narrow tolerances. The suspension system includes air bladders that support an outrigger frame that, in turn, supports the blender frame. When the bladders are inflated to a nominal pressure of 50 psig (gauge pressure of 0.34 MPa), the outrigger floats between upper and lower limit stops. Flexible inlet and outlet connections are needed to accommodate the flotation: The liquid-supply line is a polytetrafluoroethylene-lined hose enclosed in stainless-steel braid. The powder-supply lines are convoluted hoses. A specially designed flexible outlet assembly includes a sloped enclosed trough that enters a vertical discharge pipe through a loosely fitting notch in the pipe. A boot on this assembly encloses the process stream and accommodates the flotation of the blender as a whole, the motion of the discharge gate, and the motion of a transparent cover on the top of the pipe that moves with the discharge-gate actuator linkage.

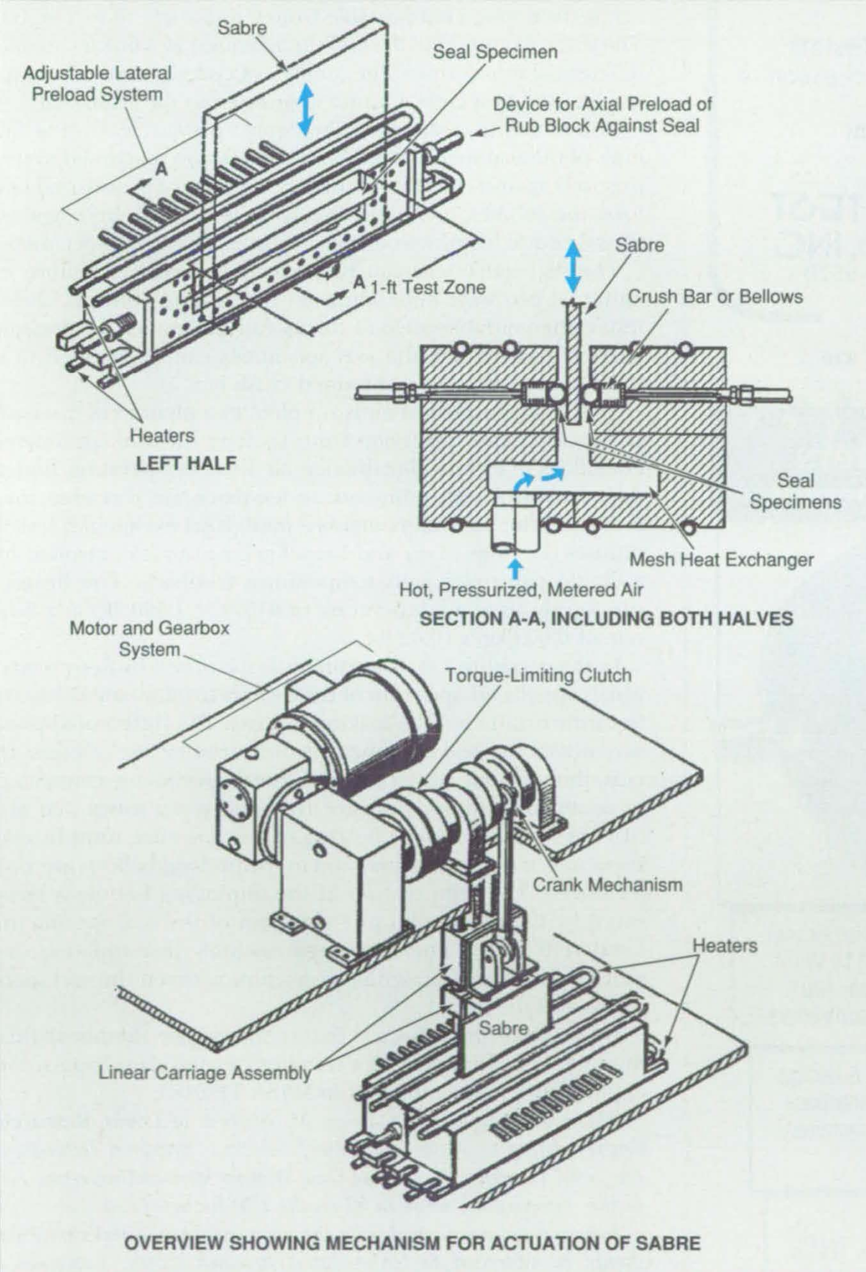
*This work was done by Joel Crook of Thiokol Corp. for* **Marshall Space Flight Center**. *For further information, **write in 81** on the TSP Request Card.*
*MFS-31126*

# Apparatus for Testing Sliding Seals for Hypersonic Engines

## Seals are exposed to high-temperature conditions like those expected in service.

*Lewis Research Center, Cleveland, Ohio*

An apparatus is designed for testing specimens of sliding seals that are under consideration for use in advanced hypersonic aircraft engines. These variable-area-ratio engines require movable panels and panel seals to maximize engine thrust over the mach range of 0 – 25 (mach 1 = speed of sound). The sliding seals are needed to prevent the leakage of hot, pressurized engine gases through the gaps between the sliding panels and the walls. Several proposed designs for these seals were described in prior articles in *NASA Tech Briefs*; these articles were "Dynamic, High-Temperature, Flexible Seal" (LEW-14672, U. S. Patent no. 5,014,917), Vol. 13, No. 4 (April, 1989), page 101; "Dynamic, High-Temperature, Flexible Seals" (LEW-14695, U. S. Patent no. 4,917,302), Vol. 16, No. 3,




This **Hot Dynamic Seal Rig** is an apparatus for testing sliding seals under conditions like those anticipated in advanced hypersonic engines.

(March, 1992), page 71; "High-Temperature, Flexible, Pressure-Assisted Brush Seal" (LEW-15086, U. S. Patent no. 5,076,590), Vol. 17, No. 2 (February, 1993), page 74; and "High-Temperature, Flexible, Fiber-Preform Seals" (LEW-15085, U. S. Patent no. 5,082,293), Vol. 17, No. 2 (February, 1993), page 75.

Using air as the test gas, the apparatus can measure leakage at temperatures from ambient to 815 °C (1500 °F) and differential pressures up to 690 kPa (100 psi). The performance of the seal specimens can be measured while sealing against flat or distorted walls. In the apparatus, two horizontal seal specimens are preloaded against opposite sides of a device called a "sabre," which is a plate that simulates an engine wall and is slid transversely to the axes of the seals (that is, vertically) to simulate the scrubbing motions anticipated in engines. The surface of the sabre can be made flat or distorted and smooth or rough, as needed, to test the performance and durability of the seal specimens.

The length of the seal specimens and the corresponding long horizontal dimension of the sabre is about 30 cm (1 ft). The range of vertical motion of the sabre is ±5 cm (±2 in.).The sabre is moved vertically by use of a motor, gearbox, and crank; the average vertical speed is adjustable from 0 to 5 cm/s (0 to 2 in./s). The vertical position of the sabre is measured by a linear variable-differential transformer. The number of cycles of vertical motion is measured by a cycle counter connected to the crankshaft.

Rub blocks (not shown in the figure) prevent leakage at the ends of the seal specimens. The rub blocks are machined to seal precisely against the ends of the sabre. By use of pressurized bellows, the rub blocks are pneumatically preloaded, both against the sabre and lengthwise against the ends of the seal specimens.

The seal specimens can be preloaded against the sabre in either of two ways depending on the sealing concept under test; either variable-preload forces can be applied by pressurized bellows, or else the seal specimens can be crushed to a fixed extent by use of a shimmed crush bar.

Metered, pressurized air is supplied to a plenum in the base of the apparatus, upstream from (below) the seal specimens. Four 3.5-kW electrical-resistance air heaters operating under digital control with temperature feedback are threaded into the base. The plenum contains a mesh heat exchanger, which diffuses the flows of air and heat. Each heater is controlled by a digital controller with temperature feedback. The heaters can supply air at a temperature of 815 °C ( 1,500 °F) at a flow rate of 0.009 kg/s (0.02 lb/s).

Leakage past the seal specimens is measured by flowmeters, which are placed upstream of the heaters to eliminate the need to capture and cool the leaking hot gas. The differential pressure across the seal specimens is measured by use of pressure taps, immediately upstream of the seal specimens, connected to room-temperature pressure transducers via tubes that are >15 cm long to prevent heating of the pressure transducers. Pressures in the seal cavities and in the preload bellows are also measured. The temperature of the impinging hot air is measured by thermocouples just upstream of the seal specimens. Load cells in the linear carriage assembly that supports the sabre measure seal drag; that is, friction between the seal specimens and the sabre.

NASA Lewis used this test fixture to evaluate the hot sliding durability performance of a number of candidate hypersonic engine seals, as documented in NASA TP-3483.

*This work was done by Bruce M. Steinetz of* **Lewis Research Center,** *Jeffrey H. Miller and Paul J. Sirocky of Sverdrup Technology, Inc., and Lawrence A. Kren of Case Western Reserve University. For further information,* ***write in 83*** *on the TSP Request Card.*

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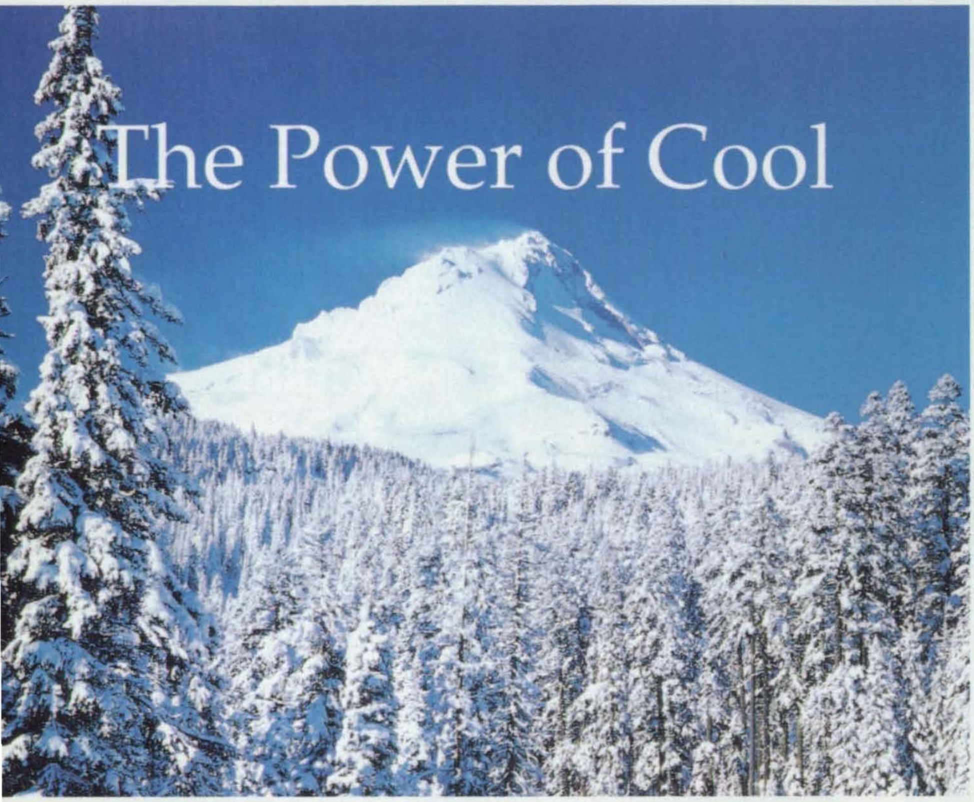


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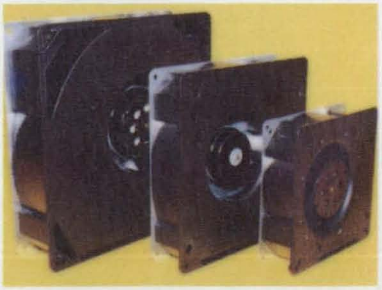

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## FEATURE



## ELECTRONICS TECH BRIEFS



## DEPARTMENTS



**On the cover:**

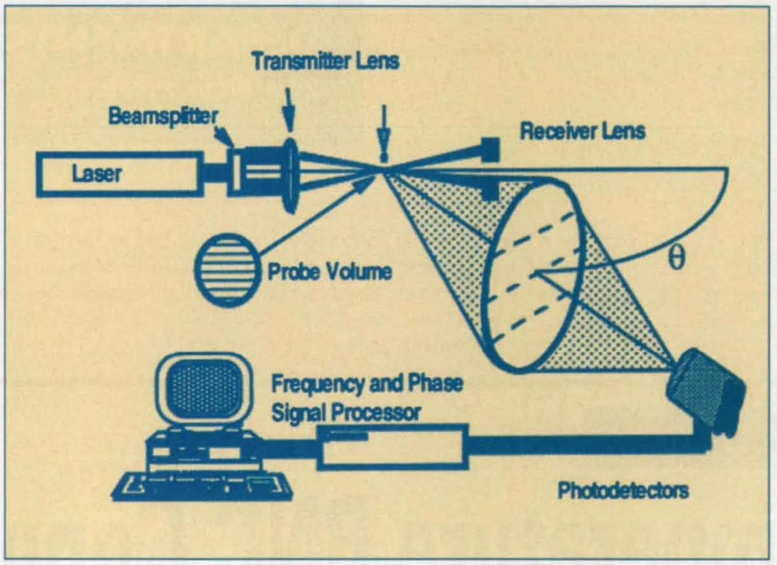
The ADA-100 Airborne Droplet Analyzer icing probe from Aerometrics Inc., Sunnyvale, CA, is intended for use with the company's phase Doppler system both on board aircraft and in simulated icing conditions such as those created in NASA's Lewis Research Center Icing Research Tunnel. NASA Lewis has supported the development of the laser instrumentation for analyzing icing and corrosion. See feature article on page 2a. *Photo courtesy Aerometrics Inc.*

# Advanced Probe Fights Icing and Corrosion

The Naval Air Warfare Center–Aircraft Division (NAWCAD) in Trenton, NJ, is currently using an Aerometrics Inc. phase Doppler particle analyzer (PDPA) system with an ADA-100 icing probe in jet-engine specification tests for corrosion and icing. These tests require specific inlet-duct conditions to be set for engine testing and certification.

The corrosion tests utilize salt-water sprays to duplicate corrosive effects of the type that carrier-based operations would have upon a jet engine. The icing tests require supercooled water sprays to simulate conditions that can lead to ice accretion at the engine inlet and foremost compressor stages.

NASA's Lewis Research Center (LeRC) supported the development of laser instrumentation based on the phase Doppler method for determining median volume diameter and liquid water content. The instrumentation was to be used both on board aircraft, as a research tool, and in simulated icing conditions such as those provided by LeRC's Icing Research Tunnel.




Schematic of the phase Doppler particle analyzer.

The aim of the program was to develop a rugged, reliable, and accurate icing probe with a large size range and negligible perturbation of the flow field. The probe had to be compact enough to work in small facilities and capable of long-term operation during heavy icing conditions. Data acquisition needed to be fast and efficient, especially in flight. Work with Aerometrics of Sunnyvale, CA, resulted in the ADA-100 (Airborne Droplet Analyzer) icing probe.

The NAWCAD system consists of the Aerometrics PDPA with an integrated software-controlled two-axis traverse system that can survey a 72-in. duct rapidly and precisely. Two multiplexed ADA-100 transmitter/receiver probe assemblies supply continuous sizing information used to adjust spray nozzles until a droplet distribution with a droplet median volume ($D_{v0.5}$) of 20 μm is measured.

The system uses an argon-ion laser with fiber optic alignment and distribution hardware capable of delivering a pair of green or blue beams to each probe transmitter simultaneously, as well as a real-time signal analyzer that can measure very dense high-velocity aerosol sprays. The system provides the necessary measurements of velocity and number density, as well as a mass flux algorithm.

The Navy specification calls for a uniform flow field across the engine inlet duct with the droplet median volume cited above for both tests. Other pertinent flow characteristics (velocity, temperature, etc.) and jet-engine operating parameters are changed to simulate various test points. Inlet duct diameters range from approximately 28 to 72 in., and the required flow field is generated by a bank of air-assist flow nozzles approximately 15 to 20 ft. upstream of the jet engine's inlet.

The phase Doppler method is based upon the principles of light-scattering interferometry. Measurements are made at a small nonintrusive optical probe volume defined by the intersection of two laser beams. As each of the spherical particles passes through the probe volume, it scatters the beams, creating an interference fringe pattern. A receiving lens strategically located at an off-axis collection angle projects a portion of the fringe pattern onto several detectors. Each detector produces a Doppler burst signal with a frequency proportional to the particle's velocity. The phase shift between the Doppler burst signals from the different detectors is proportional to particle size.

Aerometrics has developed a method to directly measure the sample volume simultaneously with particle size and velocity, enabling an accurate determination of the particle number density and volume flux. The phase Doppler method requires no calibration, because the particle size and velocity are dependent only on the laser's wavelength and optical configuration. PDPA measurements are not based upon the scattered light intensity, and consequently are not subject to errors in dense particle and combustion environments, making the method ideal for studying fuel-injector systems. The optical transmitter and receiver may be traversed together to move the location of the optical probe for spatial mapping of the flow field and of particle size distributions.

*For more information, contact Dena King at Aerometrics Inc., (408) 738-6688; fax (408) 738-6871.*

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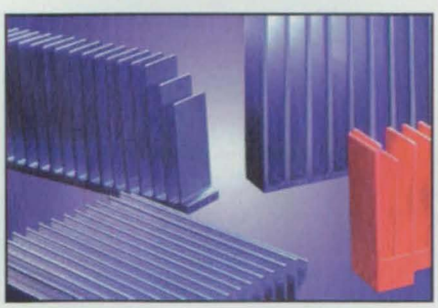

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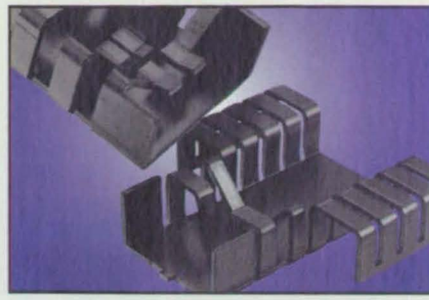

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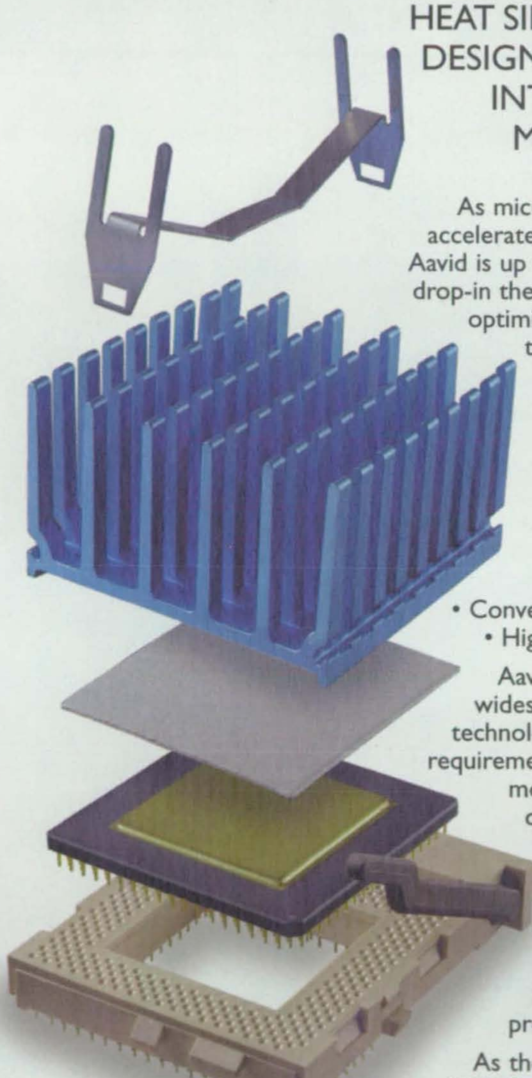

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## A compact and portable design makes the system attractive for small-part inspection, threat detection, and surveillance in remote locations.

*Naval Research Laboratory, Washington, D.C.*

The Naval Research Laboratory (NRL) has developed an intense pulsed x-ray source that is extremely portable. The applications of this technology include *in-situ* testing of x-ray detectors and CCD imaging arrays, dental x-ray imaging in remote locations, *in-situ* examination of injured human extremities, and on-site examination of small archeological artifacts (when used with a CCD imaging panel). In addition, because the system employs short (50 ns) pulses, this technology has stop-motion capabilities that will find use in imaging small animals without the need for anesthesia, as well imaging device components while the device is operating.

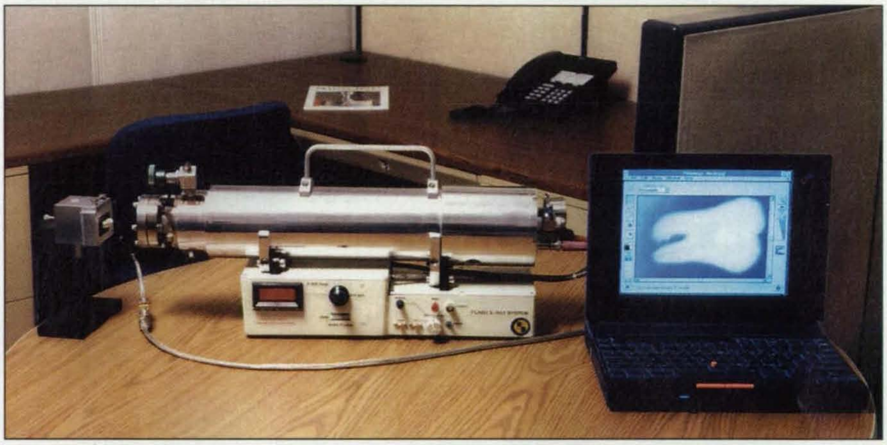
Pulsed shadowgraph radiography was developed in 1938 as a means of observing extremely rapid motion when the subject was obscured from observation with visible light. To date, flash radiography has been the principal means of observing lensed implosions and ballistic impacts over microsecond time scales. The majority of these systems are based upon the Marx circuit, which can be viewed as a distributed transmission-storage line.

NRL's flash generator is an improvement over existing pulsed x-ray sources in that the x-ray tube, Marx generator, and pulse-shaping circuit are integrated into a single cylindrical pressurized housing with the triggering electronics and high-voltage supply in an adjoining electromagnetic-interference-shielded enclosure, below the x-ray generator. Conventional and older flash x-ray generators consist of rack-mounted power supplies and can weigh hundreds of pounds.

This Mobile X-Ray Unit (MXU) is independent of the power grid and is quite compact, weighing only 26 lb. NRL integrated compact oscillator power supplies with a novel Marx drive x-ray system and has developed a truly portable x-ray pulse generator that can generate user-defined x-ray pulse duration and energy. When combined with an x-ray detector, of the type developed for dental x-ray imagery and controlled by a notebook computer, the MXU becomes an instrument that can be used in remote or confined space for x-ray inspection, security surveillance, and medical applications. The system is detector-limited, but companies around the world are actively developing large-format high-resolution real-time imaging systems that could be adapted for x-ray imaging.

Other advantages of the MXUs (a field-emission x-ray device) as compared to transitional thermionic x-ray tubes are:

- Intense x-ray flux: dose at the tube window >3 rad/cm$^2$ and repeatability more than 95 percent; short pulse duration;
- 50-ns x-ray pulse width, which eliminated integrated noise in CCD arrays and motion blurring in rapid-motion radiography, and complete portability;
- Internal battery can supply >150 pulses, and the system can be recharged by a 12-V vehicle voltage supply or 115-VAC mains.



The **Mobile X-Ray Unit** developed at the Naval Research Laboratory.

*This work was done by C.N. Boyer, Glenn E. Holland, and John F. Seely for the* **Naval Research Laboratory**. *Inquiries concerning rights for the commercial use of this invention should be directed to the Office of Technology Transfer, Code 1004, Naval Research Laboratory, 4555 Overlook Ave. SW, Washington, DC 20375-5320; (202) 767-7229; fax (202) 404-7920.*

# Three-Dimensional Long-Trace Profilometer

## Figures of cylindrical and conical surfaces can be measured without contact.

*Marshall Space Flight Center, Alabama*

An interferometric optical noncontact metrological instrument measures the three-dimensional surface figures of optical components with high precision. The instrument is designed especially for measuring (1) the interior surfaces of glass and metal cylinders and cones that are used as glancing-incidence reflectors in x-ray telescopes and (2) the exterior surfaces of polished mandrels from which thin-shell metal conical and cylindrical optics are made. The instrument is a modified version of the Long Trace Profilometer II (LTP II), which is a commercial slope-measuring interferometer that, during the past decade, has become the de facto world standard for synchrotron-radiation x-ray mirrors. Results from the proof-of-principle experiment indicate that the modified LTP II is capable of three-dimensional measurement of surfaces of typical telescope parts with slope errors less than one microradian and height errors as small as a few nanometers.

The unmodified LTP II performs a horizontal line scan with two parallel

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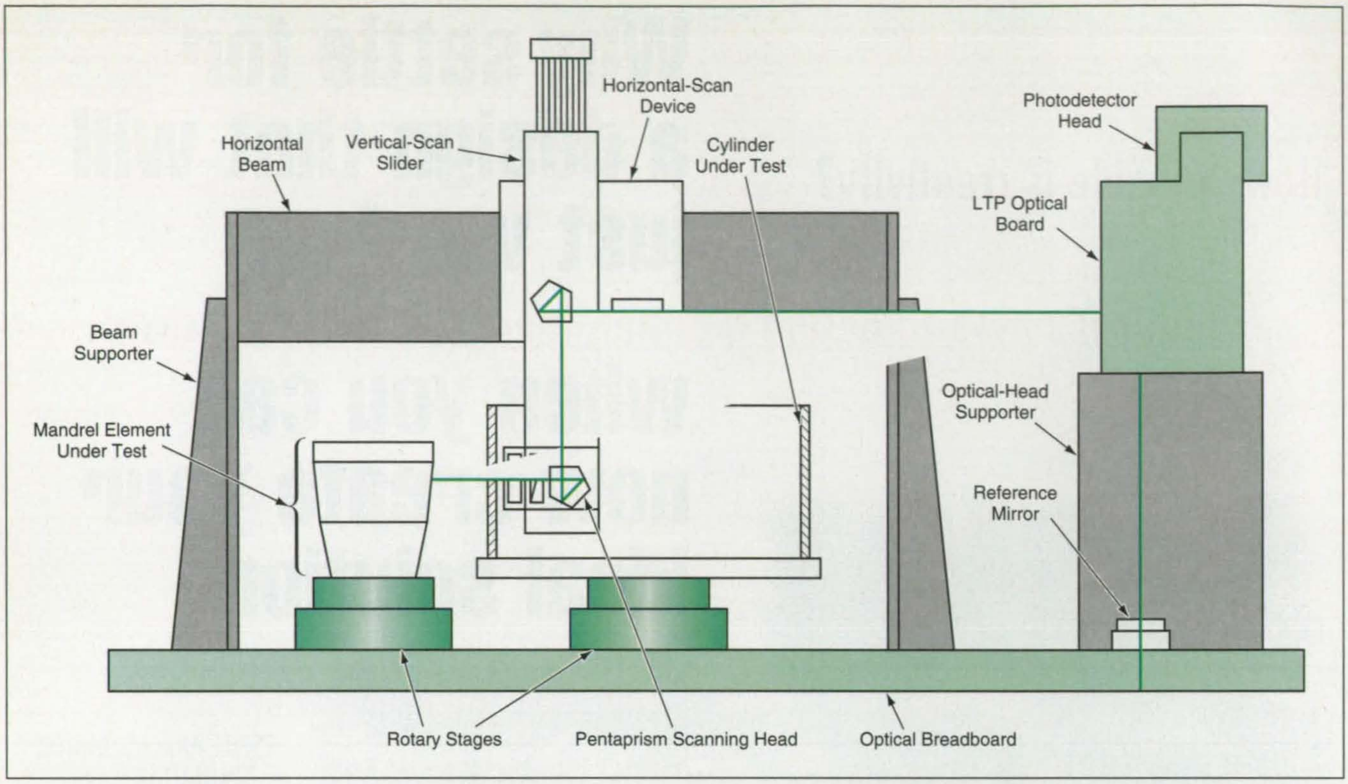


Figure 1. In the **Modified Long-Trace Profilometer**, the optical head is fixed to a breadboard table. A linear translation stage provides vertical motion for the probe beam. The probe beam as shown here is configured for both the interior of a telescope cylinder and the exterior of a mandrel.

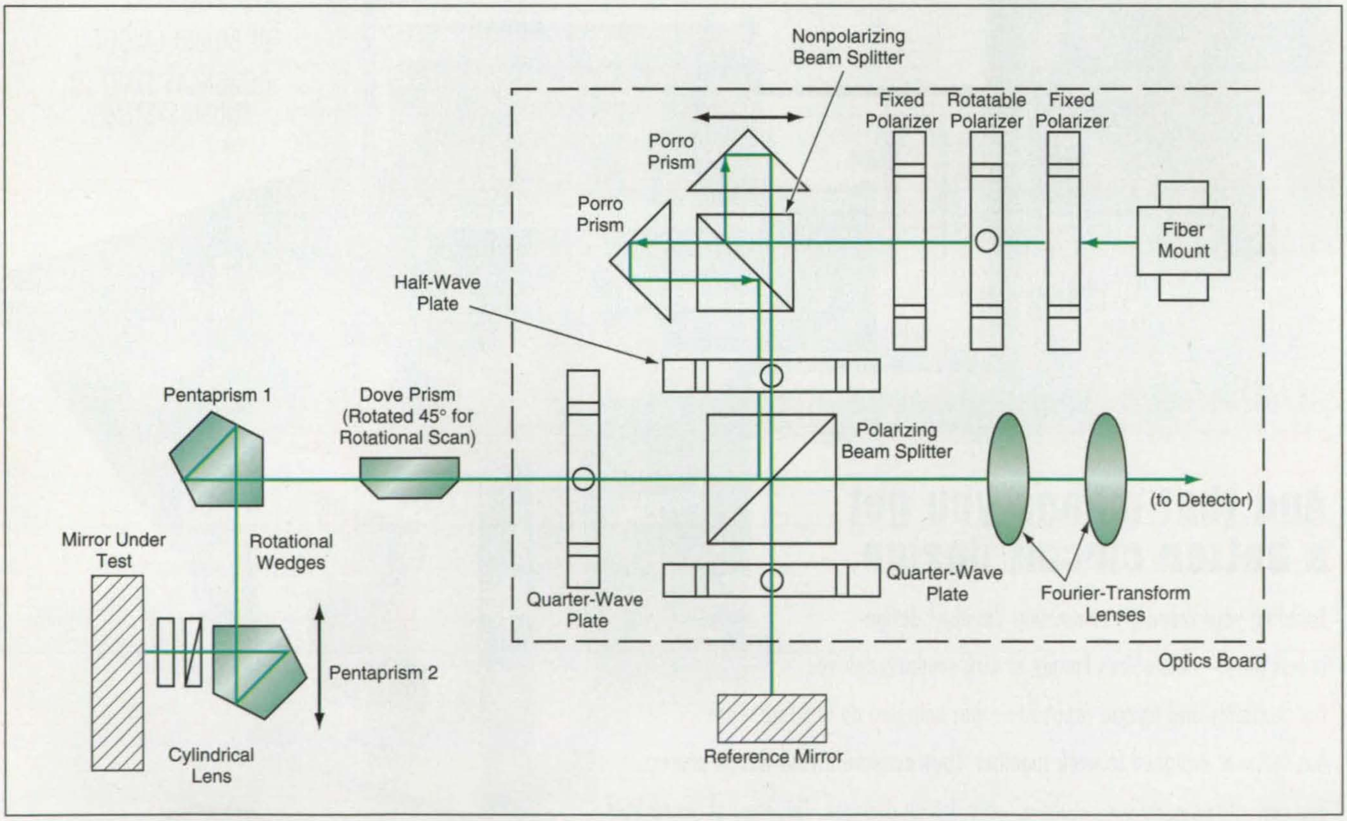


Figure 2. The **Major Components of the Optical Head** are shown here schematically. Items enclosed in the dashed-line box are parts of the unmodified LTP II. Other items are additions needed for the vertical-scanning capability.

and mutually coherent probe laser beams aimed downward onto an approximately or nominally horizontal surface. The two beams are separated by 1 mm along the horizontal scan axis. The optical and optoelectronic subsystems of the unmodified LTP II are contained in an optical head that is scanned by moving it along a bridgelike structure that stands over and spans the mirror or other surface under test.

The difference between the heights of the surface at the two beam spots is measured in terms of the difference between the phases of reflections of the two

probe beams, and this difference in height divided by the horizontal distance between the probe beams is taken as a direct measure of the local surface slope in the vertical plane defined by the laser beams and scan line. The slopes thus measured can be integrated along the scan axis to obtain the relative surface height as a function of position along the scan axis; this amounts to two-dimensional information about the scanned surface.

The LTP II was modified into the present instrument to satisfy a need for three-dimensional measurements of nominally or approximately vertically oriented surfaces — especially vertically oriented cylinders and cones. (In the case of highly precise conical and cylindrical x-ray-telescope reflectors, the vertical orientation is necessary to minimize surface errors caused by sagging of the reflectors under their own weights.) The modification included the addition of a vertical translation stage for the optical head, plus a rotary stage for turning the cylinder or cone of interest about a vertical axis (see Figure 1); together, these stages provide a two-dimensional scan, which enables complete (three-dimensional) characterization of the scanned surface.

A pair of pentaprisms mounted on the vertical-translation stage make it possible to direct the laser beams at right angles onto the scanned mirror surface, with no error introduced into the measurement by imprecise motion of the translation stage. To provide an adjustment for scanning a conical (as distinguished from a cylindrical) surface, the modification of the LTP II also included the addition of means for offsetting the direction of the probe beams by use of a pair of Risley prisms. This adjustment enables one to add a bias to the direction of the probe beams so that they are normal to the average tilt angle of the surface. One of the benefits of this adjustment is that the measurement light spot remains centered on the array of photodetectors and utilizes the entire dynamic range of the system.

*This work was done by Haizhang Li of Continental Optical Corp. for* **Marshall Space Flight Center**. *For further information, **write in 28** on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (205) 544-0021. Refer to MFS-26386.*

# Fast, High-Sensitivity Dew-Point/Frost-Point Hygrometer

## Response is faster than that of a chilled-mirror dew-point hygrometer.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Figure 1 schematically illustrates an improved dew-point/frost-point hygrometer — an instrument for measuring the reduced temperature at which ambient air becomes saturated with its present water-vapor content and the vapor begins to condense to liquid water or ice. Like the relative humidity, the dew point or frost point is a useful measure of the water-vapor content of air and is widely used in meteorology and numerous other applications.

An instrument of the present type exploits feedback control of the temperature of a condensation-sensitive transducer to maintain equilibrium between condensation and evaporation. The condensation-sensitive transducer is a surface-acoustic-wave (SAW) device that serves as the resonant frequency-selecting element of a radio-frequency oscillator. The frequency of oscillation is extremely sensitive to condensation on the surface of the SAW device; thus, a change in the frequency of oscillation provides a sensitive and rapid indication that the temperature of the SAW device is at or very near the dew or frost point.

The SAW device, its oscillator circuitry, and a low-power electrical-resistance thermometer are mounted together on a thermoelectric cooler. The output of the oscillator is mixed to a lower frequency, filtered, amplified, and processed to obtain a raw digital indication of the frequency. Because the frequency depends somewhat on temperature in addition to surface condensation, the raw digital frequency-shift reading is corrected by use of frequency-vs.-temperature data derived from calibration measurements taken when the SAW device was known to be dry. The corrected frequency-shift reading thus provides the desired indication of the amount of liquid water or ice condensed on the SAW surface.

The corrected frequency-shift digital signal and the digitized output of the resistance thermometer are fed to a digital feedback controller, the digital output of which controls the current supplied to the thermoelectric cooler. The digital controller executes a feedback control algorithm that incorporates calibration parameters to adjust the temperature to correct for any deviation of the corrected frequency-shift reading from a value indicative of the onset of condensation. Thus, the controller constantly adjusts the temperature of the SAW device to track the evolving level of

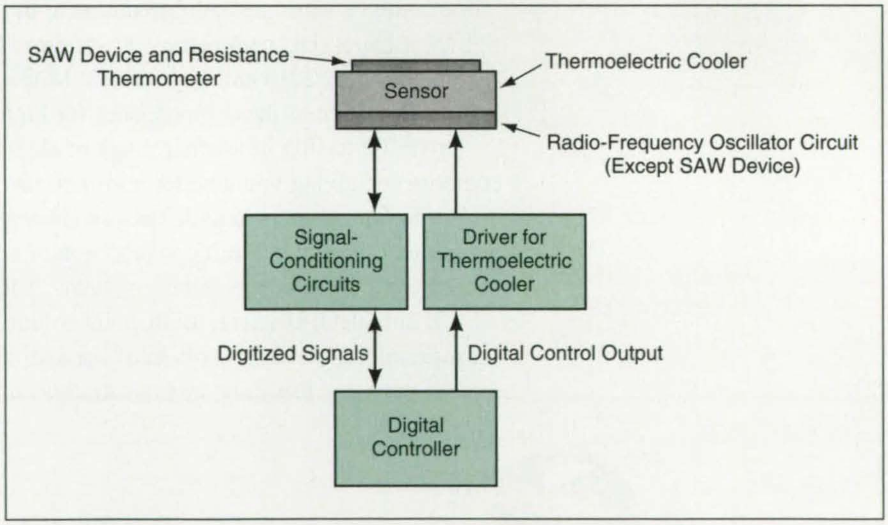


Figure 1. A **Dew-Point/Frost Point Hygrometer** of the present type operates according to a unique condensation-detection principle and to a feedback-temperature-control principle. Some aspects of the design and operation resemble those of older SAW-based and chilled-mirror dew-point/frost-point hygrometers.



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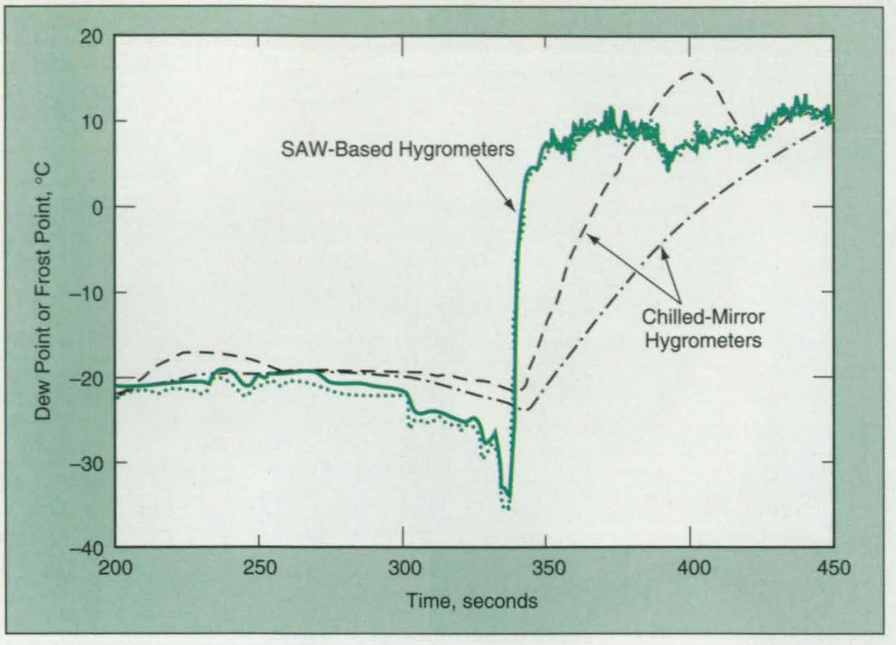


Figure 2. **Relatively Small, Rapid Changes** in the dew point or frost point can be tracked by the hygrometers of the present type, but are missed by the chilled-mirror hygrometers.

moisture in the ambient air, and the output of the resistance thermometer therefore necessarily indicates the temperature of the onset of condensation; that is, the dew or frost point.

Two dew-point/frost-point hygrometers of the present type were tested alongside two state-of-the-art commercial chilled-mirror hygrometers, which are based on a similar principle in that they measure changes in condensation optically — in terms of changes in the reflectivities of chilled mirrors. The tests involved exposure to external air during the descent of an airplane. The data acquired during the tests (see Figure 2) indicate that the steady-state accuracy of the present SAW-based hygrometers is comparable to that of the chilled-mirror hygrometers, and that the present hygrometers respond much faster to changes in the dew point.

*This work was done by Michael E. Hoenk of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, write in 13 on the TSP Request Card.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

*Larry Gilbert, Director*
*Technology Transfer*
*California Institute of Technology*
*Mail Code 315 - 6*
*Pasadena, CA 91125*
*(818) 395-3288*

*Refer to NPO-20006, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# Polarimetric Microwave Radiometry for Measuring Ocean Winds

## Anisotropy of thermal radiation is related to wind and its effects on waves.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A developmental method of estimating ocean-surface wind velocity is based on the interactions between winds and waves and the resulting anisotropy of thermal radiation emitted by the ocean surface. The method involves remote sensing by one or more polarimetric microwave radiometer(s) aboard an aircraft, which circles the ocean location of interest so that measurements can be taken at a suitable angle or angles of incidence (typically, 40° or 50°) and various azimuth angles. The polarimetric radiometric data are processed into Stokes parameters (see

$$\text{Stokes Vector} = \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} = \begin{bmatrix} T_v + T_h \\ T_v + T_h \\ T_p + T_m \\ T_l + T_r \end{bmatrix} = c \begin{bmatrix} \langle E_h E^*_h \rangle + \langle E_v E^*_v \rangle \\ \langle E_h E^*_h \rangle - \langle E_v E^*_v \rangle \\ 2\,\mathrm{Re}(\langle E_v E^*_h \rangle) \\ 2\,\mathrm{Im}(\langle E_v E^*_h \rangle) \end{bmatrix}$$

$T_h$ : Brightness Temperature in Horizontal Polarization
$T_v$ : Brightness Temperature in Vertical Polarization
$T_p$ : Brightness Temperature in 45° Polarization
$T_m$ : Brightness Temperature in –45° Polarization
$T_l$ : Brightness Temperature in Left-Hand Circular Polarization
$T_r$ : Brightness Temperature in Right-Hand Circular Polarization

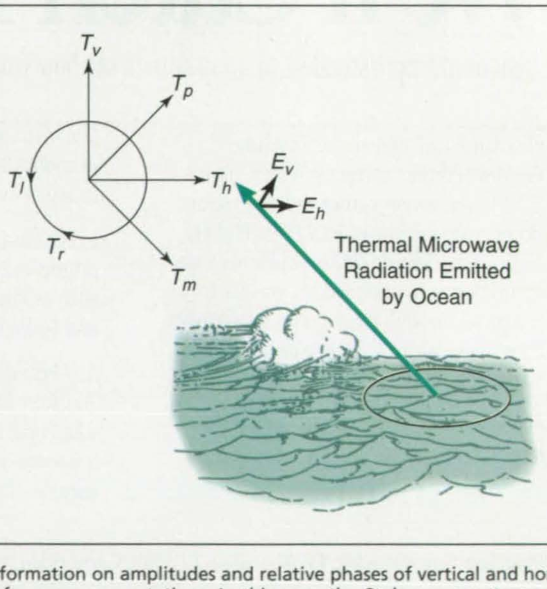


Figure 1. The **Stokes Parameters** (the components of the Stokes vector) summarize the information on amplitudes and relative phases of vertical and horizontal polarization components of the received radiation in a form that is convenient for some computations. In this case, the Stokes parameters are expressed in terms of brightness temperatures in the various polarizations.

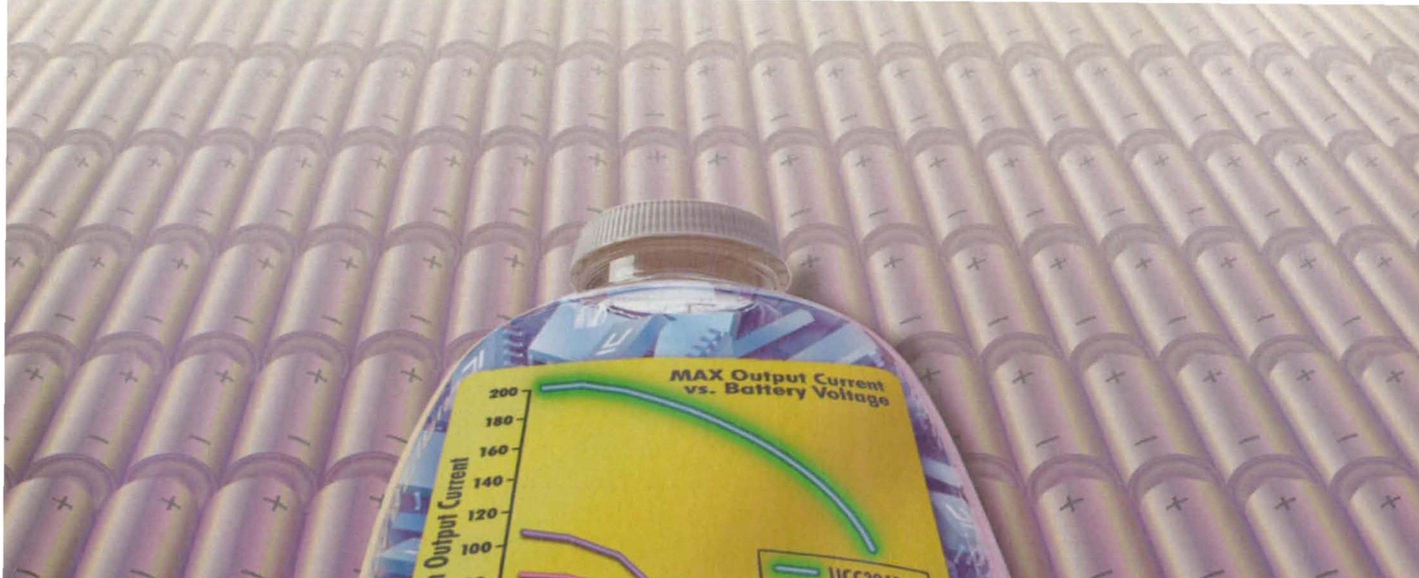


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Figure 1). The azimuthal dependence of the Stokes parameters can be taken as an indication of the direction of the wind.

Figure 2 illustrates a polarimetric radiometer designed to take the required readings in initial experiments at a frequency of 19.35 GHz. The electric fields entering the antenna are split into horizontal and vertical (from the observation perspective) polarization components $E_h$ and $E_v$, respectively, by an orthogonal-mode transducer. A waveguide switch network then produces four polarizations from $E_h$ and $E_v$. A magic tee in the waveguide switch network is used to form the sum and the difference of the vertically and horizontally polarized electric fields to produce the +45° and -45° linear polarizations with the phase shifter set at the 0° phase-shift position. If the phase shifter is set at the 90° phase-shift position by a manual switch, the +45° and -45° linear polarizations become right- and left-hand circular polarizations. At each polarization setting, 22 pairs of antenna and reference load measurements are taken, corresponding to an integration time of 88 ms, and are reduced to one brightness-temperature sample. Four polarizations, including vertical, horizontal, -45° linear (or left-hand circular), and +45° linear (or right-hand circular) polarizations, are scanned sequentially, with switch positions commanded by a personal computer, to obtain four brightness-temperature samples, $T_v$, $T_h$, $T_m$ (or $T_l$), and $T_p$ (or $T_r$).

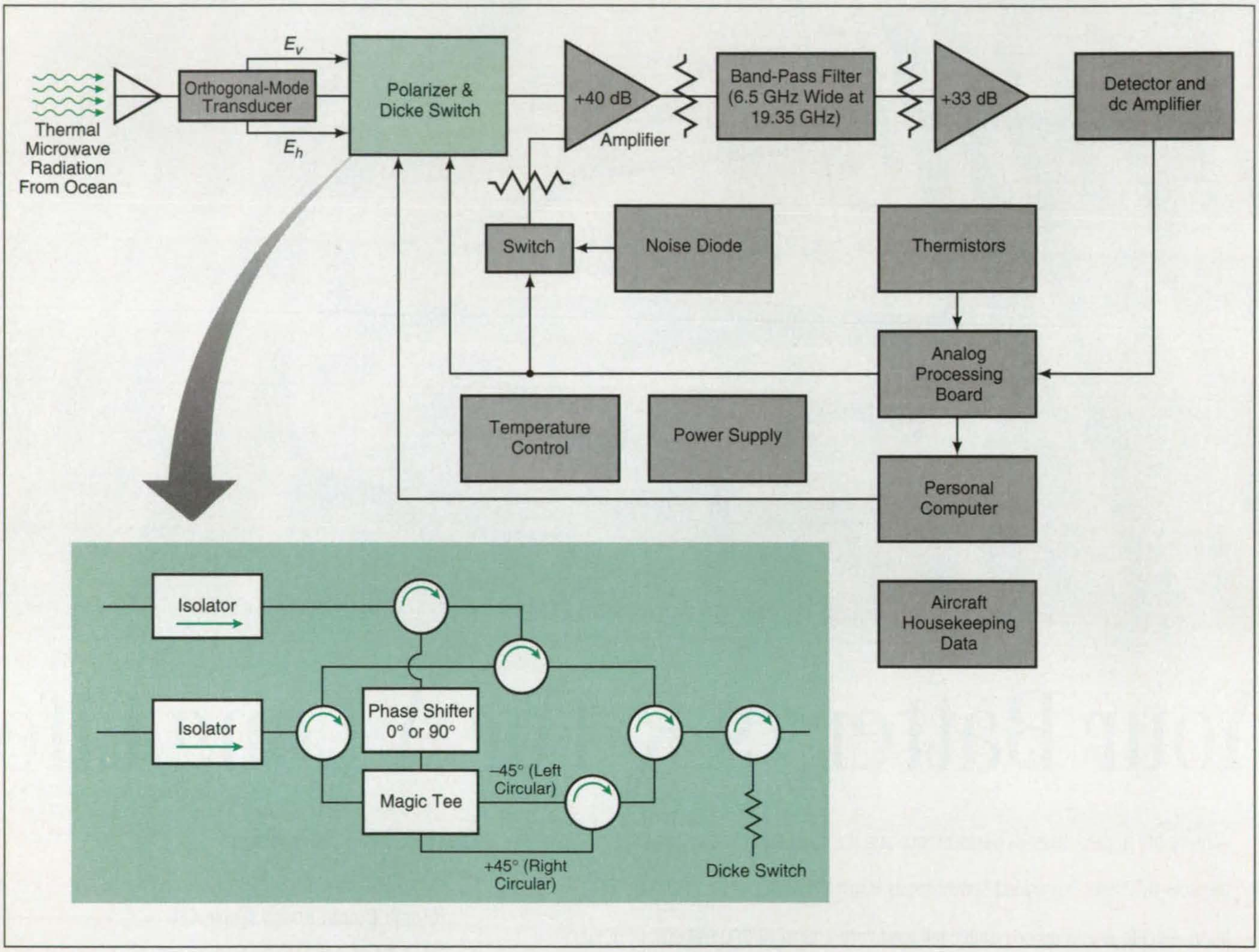



Figure 2. This **Polarimetric Radiometer** includes a waveguide switch network containing a magic tee; this network forms the various polarization components in preparation for measuring the brightness temperatures in those components.

A second radiometer designed to operate at a frequency of 37 GHz is similar, except that it does not include the 90° phase shifter. Moreover, for lack of time, the 90° phase shifter in the 19-GHz radiometer was not used in initial experiments, so that data on $T_l$ and $T_r$ were not obtained and thus the fourth Stokes parameter was not determined. In one set of experiments, the 19-GHz polarimetric radiometer took readings at angles of incidence of 30° to 50°, from a DC-8 airplane circling wind-measuring buoys moored in the Pacific Ocean off the northern California coast. In a second set of experiments, both radiometers took readings at angles of incidence of 45°, 55°, and 65°. In both sets of measurements, the Stokes parameters in units of brightness temperature exhibited upwind-vs.-downwind anisotropies of the order of a few Kelvins; this finding lends credence to the hypothesis that microwave polarimetric radiometry can be used to determine the direction of the wind at the surface of the ocean. Presumably, the amplitudes of the azimuthal dependences of the Stokes parameters are indicative of the speed of the wind, but quantitative relationships between these amplitudes and wind speeds have yet to be established.

*This work was done by Simon H. Yueh, William J. Wilson, Son V. Nghiem, and Fuk K. Li of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, write in 15 on the TSP Request Card.*
*NPO-19583*

# Toughened High-Temperature Ceramic

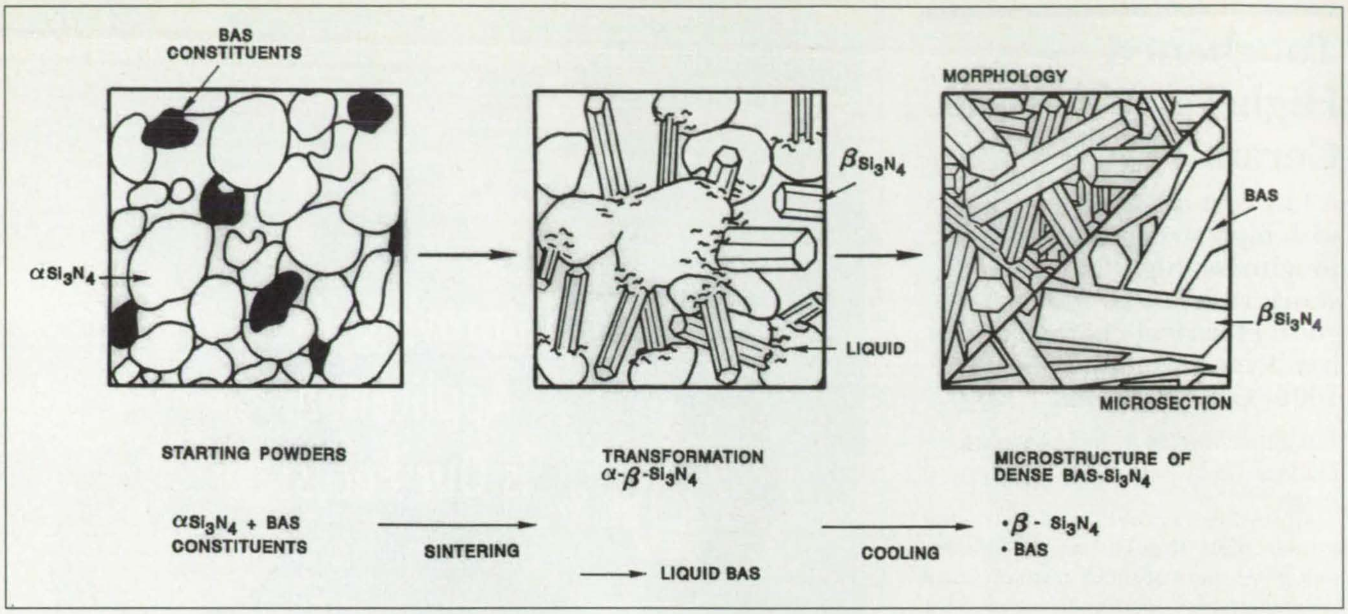
**A low-cost advanced ceramic with high strength and toughness, high thermal shock resistance, and good electrical characteristics has been developed for 1000-°C applications.**

*Lockheed Martin Vought Systems, Dallas, Texas*

Advanced ceramic materials that exhibit high strength and toughness with good thermal shock resistance and low dielectric properties are needed for emerging high-temperature engineering applications. A recently developed *in-situ* reinforced barium aluminosilicate (BAS) glass-ceramic shows promise of meeting many of the requirements for these types of applications with the added benefit of low-cost fabrication through densification by pressureless sintering. The BAS glass ceramic is toughened through *in-situ* growth of whisker-like ß-silicon nitride ($Si_3N_4$) grains resulting from the α-ß $Si_3N_4$ phase transformation. Developed for missile radomes, the material's other potential applications include components in electronic packaging, low-loss electric windows, armor, cutting tools, and other structural applications.

A $Si_3N_4$/BAS slurry is prepared by ball-milling mixtures of high-content α-$Si_3N_4$, barium carbonate, aluminum oxide, and silicon dioxide along with a fugitive binder and a dispersant. The resulting slurry can be used for slip-casting of components or can be further processed by spray-drying to yield a flowing powder for use in the fabrication of parts by conventional dry pressing or cold isostatic pressing methods.

The organic materials are burned out and the "green" components are densified by pressureless sintering at temperatures between 1750-1800 °C. During densification, the material reaches a temperature at which the BAS constituents and the $Si_3N_4$ react to form a liquid phase. Transformation of the $Si_3N_4$ takes place in the presence of the liquid phase, during which whisker-like elongated ß-phase $Si_3N_4$ grains are formed. Upon cooling, the whisker-like grains (reinforcement phase) are surrounded by a secondary matrix phase composed of crystalline BAS to form an *in-situ* reinforced barium aluminosili-




Process for the formation of *in-situ* reinforced **Barium Aluminosilicate Composites.**

cate (IRBAS) composite.

The resulting advanced ceramic material exhibits excellent mechanical, thermal, and electrical properties and can be tailored to specific applications through control of the composite constituents. For a 30-percent BAS/70-percent $Si_3N_4$ composition, flexure strengths up to 565 MPa and fracture toughnesses up to 5.74 MPa-$\sqrt{m}$ are typical. Thermal properties include a low coefficient of thermal expansion (3.8 × 10-6/°C) and high thermal conductivity (9.19 W/(cm•K)), which provides good thermal shock resistance. Electrical properties include a dielectric constant of 7.75 and a dielectric loss of 0.001. The material is currently being used in missile radome applications at temperatures up to 1000 °C.

*This work was done by Kerry Richardson and David Hunn of* **Lockheed Martin Vought Systems**, *Dallas, TX. For further information contact them at (972) 603-9844.*

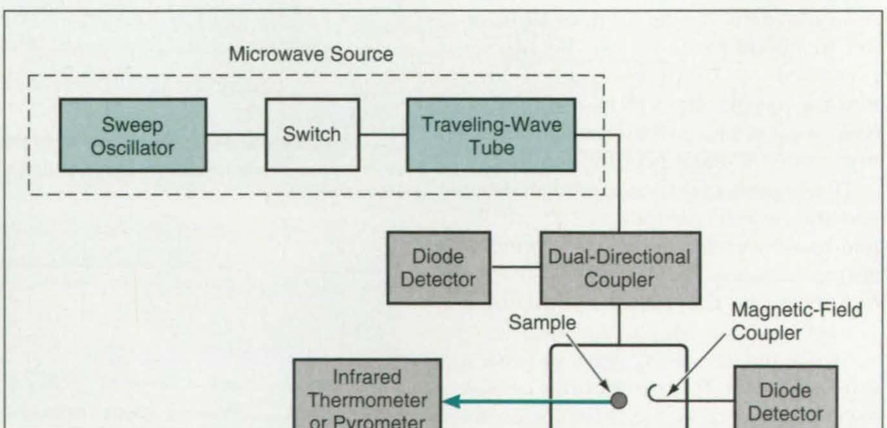
*This invention is owned by Lockheed Martin Vought Systems, and U.S. patent no. 5,358,912 has been issued. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel at Lockheed Martin Vought, (972) 603-9207.*

# Measuring Complex Permittivity of a Microwave-Heated Sample

## Complex permittivity can be determined as a function of temperature.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

An improved technique for measuring the complex permittivity of a microwave-heated sample of dielectric material provides for simultaneous control of heating power and/or measurement of the temperature of the sample. This technique is based partly on the established cavity perturbation technique, in which the real and imaginary parts of the permittivity of a small sample are calculated from the values of the resonance quality factor ($Q$) and resonance frequency ($f_r$) of the microwave cavity measured with and without the sample present. Older techniques based on the cavity perturbation technique do not provide for control of power and/or temperature, and are therefore not useful for characterizing samples at temperatures above ambient when only one microwave frequency is used for heating and detection.




This **Apparatus Uses the Same Resonant Microwave Field** to both heat the sample and measure its complex permittivity. The apparatus includes circuitry that controls the power dissipated in the sample and the walls of the microwave cavity, plus other circuitry that adjusts the microwave frequency to track the resonance of the cavity with the sample present.

The complex permittivity of a dielectric material is a measure of its microwave-absorption properties and of some other physical and chemical properties. The complex permittivity is often called the complex "dielectric constant" even though it is not constant; indeed, one could use the present technique to measure the change in the complex permittivity of a sample during microwave heating and/or other processing to monitor the extent to which the material has been converted to the desired end condition.

In the present technique, one uses the same microwave field to both heat the sample in a controlled manner and measure its complex permittivity. The apparatus used in this technique (see figure) includes a microwave source, the frequency and power of which can both be controlled. The frequency of the source is made to track $f_r$, even as $f_r$ changes somewhat with the condition of the heated sample; the $f_r$-tracking technique was described in "Measuring Q and $f_r$ of a Microwave Cavity: Part II" (NPO-19356), *NASA Tech Briefs*, Vol. 19, No. 12 (December 1995), page 36. Controlling the frequency in this way confers two benefits: First, because the frequency is always at or close to $f_r$, power is delivered efficiently to heat the sample even as the dielectric parameters of the sample change during continued heating. Second, $f_r$ can be continuously monitored by use of a frequency counter connected directly to the output of the oscillator.

Diode detectors are used to measure the forward power ($P_F$) traveling from the microwave source to the microwave cavity and the reflected power ($P_R$) traveling from the cavity back to the source, so that the net power transmitted into (and thus dissipated in) the cavity ($P_T$) can be calculated from $P_T = P_F - P_R$. The apparatus includes computer-controlled circuitry for maintaining $P_T$ at a desired value. A third diode detector connected to a magnetic-field coupler in the microwave cavity measures a power ($P_D$) that can be shown to be proportional to the energy ($E_M$) stored in the resonant electromagnetic field in the cavity.

The total power transmitted into the cavity can be expressed as $P_T = P_S + P_W + P_E$ where $P_S$ is the power dissipated in heating the sample, $P_W$ is the power dissipated in heating the wall of the cavity, and $P_E$ is the power loss in the input electronics. By continuously maintaining the critical coupling between the microwave source and cavity using an automatic impedance tracking technique developed previously, the reflected power will be zero and power dissipated in the electronics will be equal to the power dissipated in the cavity. The resonance quality factor of the cavity is then given by $Q_T = 2\pi f_r E_M/P_T$. By virtue of the equation for the power-dissipation components, one can write $1/Q_T = 2(1/Q_W + 1/Q_S)$, where $Q_W = 2\pi f_r E_M/P_W$ and $Q_S = 2\pi f_r E_M/P_S$. Then the reciprocal of the quality factor associated with the sample is given by $1/Q_S = 1/2/Q_T - 1/Q_W$. Provided that the temperature of the wall is maintained approximately constant (e.g., by cooling it with water) $Q_W$ is independent of $P_T$ and of the temperature ($T$) of the sample. By making substitutions from the equations and definitions above, the equation for $1/Q_S$ can be rewritten as $1/Q_S = P_T/2\pi f_r G_M/P_D - 1/Q_W$, where $G_M$ is the factor of proportionality between $E_M$ and $P_D$ ($G_M = E_M/P_D$). $G_M$ depends only on the geometry of the cavity and magnetic coupler and can be determined from a low-power calibration measurement in the absence of the sample. By use of cavity perturbation theory, one can compute the complex permittivity of the sample from $1/Q_S$.

In a typical experiment, one sets $P_T$ to a desired value while measuring $T$ by use of a pyrometer or other noncontact device. Once $T$ settles to a steady value,

one measures $f_r$ and $P_D$. One then increases $P_T$ in steps and repeats the measurement procedure at each step to accumulate sets of data on $P_T$, $f_r$, and $P_D$ at various increments of $T$ corresponding to the increments of $P_T$. From these data, one obtains $1/Q_S$ as a function of $T$ and thus also the complex permittivity of the sample material as a function of $T$.

*This work was done by Martin Barmatz and Henry W. Jackson of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 97*** *on the TSP Request Card.*
*NPO-19773*

# Noise and Impedance Generator for Cryogenic Testing of HEMTs

**Spurious effects from room-temperature test circuits would be reduced.**

*NASA's Jet Propulsion Laboratory,*
*Pasadena, California*

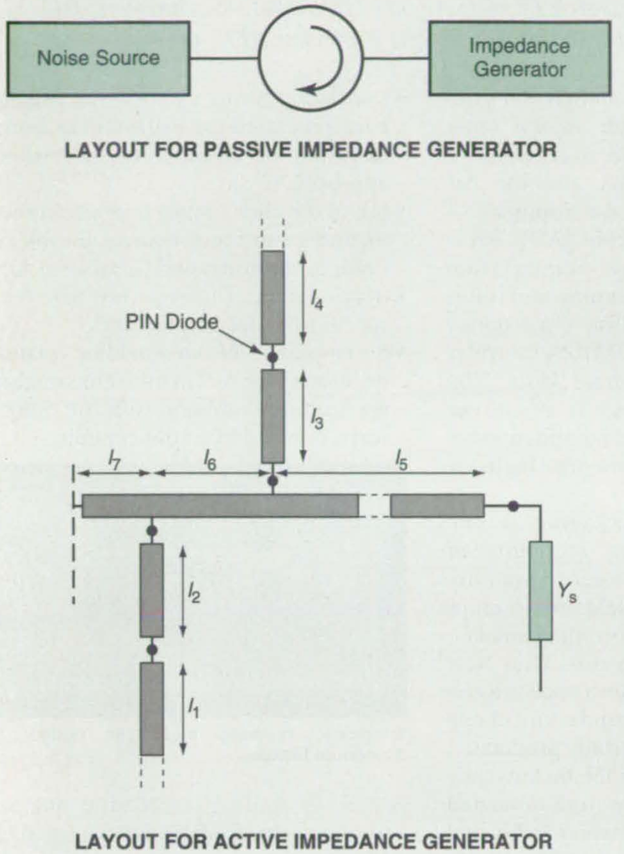
A monolithic, integrated, coolable probe is being developed for use in measuring the cryogenic noise parameters of high-electron-mobility transistors (HEMTs) at the wafer-processing stage of production. The integrated circuitry in the probe would include a noise source and impedance generator integrated with a coplanar-waveguide probe circuit.

This development is prompted by a fundamental physical limitation on the accuracy and repeatability of low-temperature HEMT noise-parameter measurements performed with commercial noise sources and impedance generators, which operate at room temperature: In preparation for such a measurement, one attaches a room-temperature noise source and impedance generator to the room-temperature ports of cryogenic, coplanar on-wafer probes. The probes are lossy and introduce noise temperatures comparable to or greater than the noise temperature of the device under test (DUT). For example, in a typical test in the frequency range of 2 to 18 GHz, the noise-temperature measurement error can go beyond ±25 K, while the noise temperature of the DUT is <10 K.

To obtain the most accurate and repeatable measurements of noise parameters at low temperatures, one should place the impedance generator within a waveguide wavelength (at the test-signal frequency) of the DUT and should use a noise source with a noise temperature comparable to that of the DUT. The developmental probe would be designed to satisfy these requirements. The probe would be compatible with other cryogenic probes designed for measuring scattering (S) parameters over a frequency range of 1 to 40 GHz. The integration and use of probes of both types would enable the efficient, accurate, and nondestructive characterization of HEMTs and of circuits that contain them. The use of these probes in characterizing HEMTs under cryogenic conditions at the wafer level would eliminate the need for the expense and labor of dicing, mounting, and wire bonding needed to characterize HEMTs by present techniques.

The figure illustrates some aspects of alternative proposed designs. Calibrated noise diodes would be inserted in a coplanar-waveguide circuit that would be coupled to the impedance generator. The topology of the impedance generator would have to be chosen to enable integration into the coplanar-waveguide format and to reduce resonant modes. One of two

proposed alternative design concepts, following a narrowband approach, calls for all passive components to minimize insertion loss and added noise. A hybrid coupler would be used to provide isolation and to pad the noise signal, and a series tapered coplanar transmission line would be used to provide up to eight predetermined impedance states.




The **Layout Is Affected** by the design of the impedance generator. Active and passive alternative design concepts are under consideration.

The other alternative design concept, following a broaderband approach, would entail the development of a low-loss active impedance generator. An optimal tuner topology could be derived for a tunable impedance network consisting of various transmission lines connected through positive/intrinsic/negative (PIN) diodes to form open shunt stubs or matched transmission lines.

The design would have to provide a proper interface between the probe and the input terminals of the DUT. The interface could be analyzed and designed by use of finite-element techniques. Among other things, the interface would have to be analyzed for propagation in higher resonant modes to enable accurate noise characterization. Gum ferrite sheet would be used as an electromagnetic absorber to suppress spurious modes. Finally, the complete three-dimensional mathematical model of the integrated active probe would be studied to insure proper signal propagation and compatibility with currently available network-analyzer facilities.

*This work was done by Joy Laskar of Georgia Tech and J. Javier Bautista of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, **write in 46** on the TSP Request Card.*
*NPO-19577*

# Low-Cost Aluminum Nitride (AlN) Microelectronic Packaging

## New material replaces aluminum oxide in high-performance microelectronic packaging.

*Carborundum Corp., Phoenix, Arizona;*
*Defense Advanced Research Projects Agency (DARPA), Washington, DC;*
*U.S. Air Force Wright Laboratory, Wright Patterson AFB, Ohio*

Carborundum Corp.'s Microelectronics Division, along with several team members, entered into a cooperative agreement with DARPA and the Air Force calling for the development of low-cost aluminum nitride (AlN) packaging for applications ranging from automobiles, wireless phones, and information systems to collision avoidance and military systems. DARPA provides funding on a 50-50 share basis. The evolving AlN technology is a dual-use product, giving substantial added value in both military and low-cost high-volume applications.

Microelectronics packaging is one of the fastest-growing segments of the burgeoning electronic communications industry. Microelectronic chips and components are becoming smaller, denser, and more powerful. Thus heat spreading and thermal dissipation are crucial to the design and manufacture of reliable state-of-the-art electronic products.

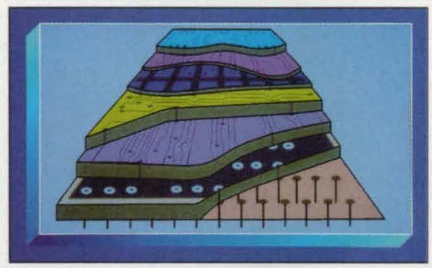
Heat management issues are currently addressed with plastics with attached heat sinks, alumina ceramics (with and without heat sinks), and beryllium oxide (BeO). AlN, however, provides designers with a high-performance, cost-effective alternative to these choices.

Beyond AlN's high thermal conductivity and electrical insulation, it can be produced as a multilayer structure, allowing 3-D wiring. Carborundum and IBM have jointly developed a lower-temperature firing process for manufacturing multilayer AlN on existing production equipment (used for alumina multilayer products). This collaboration has led to the codevelopment of several proprietary processes that allow AlN multilayer products to be mass-produced on existing manufacturing equipment.

Production of an AlN-based co-fired multilayer package consists of several distinct process steps, including ceramic powder production; tape casting, blanking, tape punching, metal printing, and lamination to form a green body; binder removal and sintering; and plating and brazing.

Carborundum and its team are taking an innovative approach in the development of low-cost AlN packaging applications. This approach includes:

- translation of the extensive knowledge base generated for high-volume manufacturing of alumina to AlN where appropriate;
- use of the core science base established to understand and control the metallization, sintering, and forming of AlN;
- development of low-cost raw materials, specifically AlN powder; and
- development of an enabling plating technology for AlN in multichip module applications consistent with the unique surface chemistry of this ceramic.



Schematic showing multilayer design of **Aluminum Nitride.**

AlN is finding increasing market acceptance in applications where thermal management issues dominate substrate selection (*i.e.*, telecommunications and radar). These markets will grow significantly as the cost of AlN substrates is reduced, both through the economies of scale and the specific cost reduction activities targeted by the agreement.

An additional goal of the cooperative agreement is to help establish a strong domestic packaging base to reverse the dominance of offshore suppliers. Japanese ceramic packaging manufacturers now supply more than 80 percent of the existing $2-billion/year market, including almost 90 percent of military hermetic packaging.

*This work was done as a collaborative effort among team members from* **Carborundum Corp.**, *IBM, Dow Chemical, Hughes Aircraft, Evans Company, and MIT (Cooperative Agreement F33615-95-2-1622). These team members retain intellectual property rights to any technological developments under the program. Inquiries concerning this work or the availability of the AlN material should be directed to Dr. Roger S. Storm, Carborundum Microelectronics, 10409 S. 50th Place, Phoenix, AZ 85044; (602) 496-5125.*

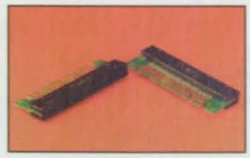
# NEW PRODUCTS

## Product of the Month

### Visual PCB Assembly Inspection System

GenRad Inc., Concord, MA, offers the Viper Visual Inspection System, designed to provide a cost-effective solution for detecting and preventing defects in the component-placement process for printed circuit board (PCB) assembly. Targeted at PCB manufacturers who are placing tens of thousands of components per hour, the system employs line scanning and a shape-based approach. It provides a full suite of techniques for detection of device presence or absence on components as small as 0.04 by 0.02 in., device orientation, and x/y and rotational position of every board component. Boards as large as 14 × 18 in. can be inspected for all component placement defects.

**For More Information Write In No. 800**



### PCI Test Connector with Long Life

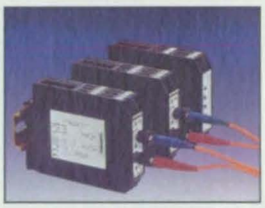
Meritec, Painesville, OH, offers a 32-bit PCI test connector specifically designed for PCI-card test applications where long life is critical. The universal connector is suitable for high-volume production requiring thousands of test cycles in continuous operation, the company says. The assembly plugs into the PCI connectors in the test bed and is actuated by the horizontal insertion of the card under test. The unit meets all PCI local bus standards (revision 2.0) for a 3.3-V or 5-V 32-bit configuration. The company plans to make the test connector available in a 64-bit version.

**For More Information Write In No. 801**

### Compact Four-Capacitor Array

A recent introduction by AVX Corp., Myrtle Beach, SC, is the 0612 four-capacitor array. Designated the W3A series, the array joins the AVX family of integrated passive components for EMI filtering on I/O lines and decoupling applications. The company says the array enables designers to reduce board space and placement costs. The series is available in a NPO dielectric with ratings between 16-100 V; a X7R dielectric with the same ratings; and a Y5V dielectric with ratings between 16-50 V. Typical pricing ranges from $0.06-$0.13 in quantities of 100,000.

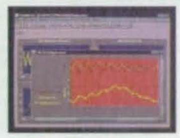
**For More Information Write In No. 802**



### Fiber Optic Data Converters

Entrelec Inc., Brossard, Quebec, Canada, says its ILPH FO fiber optic data converters increase the distance, speed, and quality of serial data transmission. The 22.5-mm-wide modules interface to RS-232 or RS-422-485 signals, converting them to a digitally modulated light beam for transmission up to 4000 m at rates to 2.5 Mb/s. Signals are immune to electrical noise, ground loops, surges, and lightning transients. External power supply voltage range is 20.4-28.8 V DC, 150 mA max. Inputs and outputs are overvoltage protected.

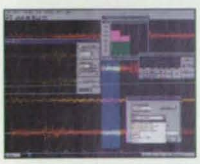
**For More Information Write In No. 803**



### Data Analysis Program for Windows NT/95

DSP Development Corp., Cambridge, MA, introduces a "native" version of DADiSP 4.0, a data analysis and signal processing worksheet, for Windows NT and Windows 95. The company says this version runs about 30 percent faster under Windows NT than DADiSP 4.0 for Windows 3.1. Added features are GUI windows, scrollbars in zoomed windows, a combo box line editor, message logging, automatic import header file generation, and enhancements to SPL, DADiSP's C-like language. This version supports 32-bit dynamic linked libraries, allowing users to create their own functions in C and add them to DADiSP to use as if they were DADiSP built-in functions.

**For More Information Write In No. 804**



### Data Acquisition System

Sony Precision Technology America, Orange, CA, is making available PCscan MK II, a data acquisition system designed to complement the features of Sony's PC200 series digital audio tape portable data recorders. Written in Windows 95 32-bit code, the system controls an A/D converter, up to 4 Gbytes of analog storage, high-speed search, real-time monitoring, and tape data format conversion. Data management capabilities include measurement of areas such as maximum, minimum, average, RMS, time, numeric data value, and sound monitor. Output formats such as binary, ASCII, DADiSP, MATLAB, Snap Master, Star, Wave, and others can be chosen.

**For More Information Write In No. 805**

### Hybrid Pulse-Width Modulation Amplifier

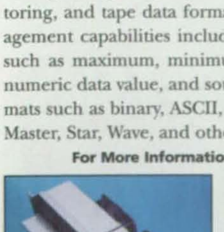
The newest addition to the line of hybrid pulse-width modulation (PWM) amplifiers from Apex Microtechnology, Tucson, AZ, is the SA02. The company says the device has an industry-first 250-kHz switching frequency, unique protection circuits, and the space savings that only a hybrid provides. Power bandwidth is out to 25 kHz. The unit has full bridge output operation and delivers 10 A continuous output with up to 800 W continuous output power. Price is $295 in hundreds. Applications include microstepping and brushless motors, magnetic bearings, vibration cancellation, and shaker tables.

**For More Information Write In No. 806**

### Keyboards and Switches for Portables

Advanced Input Devices, Coeur d'Alene, ID, offers a broad line of keyboard switch technologies for laptop, notebook, and other portable computing products. The line includes flat-panel dome and membrane, mid-travel plastic key and elastomer, and full-travel switches, and multi-function input subsystems incorporating keypads, cursor control devices, displays, and audio feedback. The company provides specification, CAD engineering, program management, PCBs, graphics, backlighting, screening, surface-mount technology, and the ability to produce complex control panels.

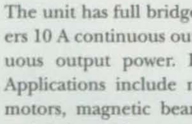
**For More Information Write In No. 807**



### Solid-State Cooling for Electronic Enclosures

Melcor, Trenton, NJ, says its TechniCOOL™ line of solid-state thermoelectric air conditioners was designed to provide reliable, environmentally friendly cooling solutions for electronic enclosures and communications equipment. Providing up to 1500 BTU/hour cooling each, they can be arrayed in series or parallel configurations for greater cooling. Because they contain no working fluids, they can be mounted in any orientation. They feature DC operation, with no acoustical or electrical noise.

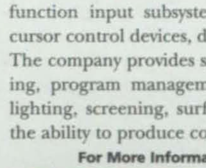
**For More Information Write In No. 808**



### Programmer for Analog ICs

Advanced Linear Devices Inc., Sunnyvale, CA, offers the E100 EPAD Programmer, designed to adjust the bias voltage of the company's analog integrated circuits called EPAD (Electrically Programmed Analog Devices). Programming is done using the E100 Programmer, a standard IBM-compatible PC with 386 or higher, DOS 3.0 or higher, Windows 3X or 95, an adapter module, and a conventional 15-V power supply. The E100 can program EPADs before insertion into a circuit or after mounting on a board, thus allowing for trimming of the entire analog circuit. Price of the E100 is $499 and of the adapter modules with control software $149 and up.

**For More Information Write In No. 809**



### Software Link for PCB Designers

ACCEL Technologies Inc., San Diego, CA, announces the availability of ACCEL Relay, the latest addition to the company's EDA family of printed-circuit board layout and design software. The program serves as a bridge: the engineer uses its preplacement and prerouting capabilities for critical PCB areas, and then forwards his input to the board designer working on the PCB layout. The in-progress design is passed back to the engineer, who can view, annotate, and redline the design. Besides working with ACCEL Schematic, Relay 12.1 can be used with Viewlogic Workview, OrCAD Capture, and other schematic entry tools.

**For More Information Write In No. 810**

# Manufacturing/Fabrication

## Sputter Texturing To Prepare Surfaces for Bonding

### Patterns are defined by small ceramic particles temporarily attached to surfaces to be textured.

*Lewis Research Center, Cleveland, Ohio*

A process for texturing the surfaces of complexly shaped metal parts includes a sputter-etching step in which the areas not to be etched are masked by small ceramic particles temporarily attached to the surfaces. By choice of the sputtering parameters and the size and distribution of masking particles, the width and depth of the textured features can be controlled over a wide range. Texturing improves bonding to other parts. The process has been used to texture metal fixtures to be anchored to composite-material (matrix/fiber) structural components. It could also be used to texture such prosthetic items as hip implants; textures could be sized and shaped to favor the ingrowth of adjacent bone to anchor the implants. [A related process for texturing molds for implants was described in "Improved Texturing of Surgical Implants for Soft Tissues" (LEW-15805), *NASA Tech Briefs*, Vol. 21, No. 1 (January 1997), page 70.]

Unlike some other texturing processes, this process does not create loosely adherent particles which could lead to the formation of wear-causing debris. The widths and depths of etch pits can be controlled so that ingrown tissue is assured of nourishment or so that an adhesive material can grip strongly. The part is not overheated during the process, and its mechanical properties are therefore not degraded. The process can be used on recessed surfaces as well as on exposed ones.

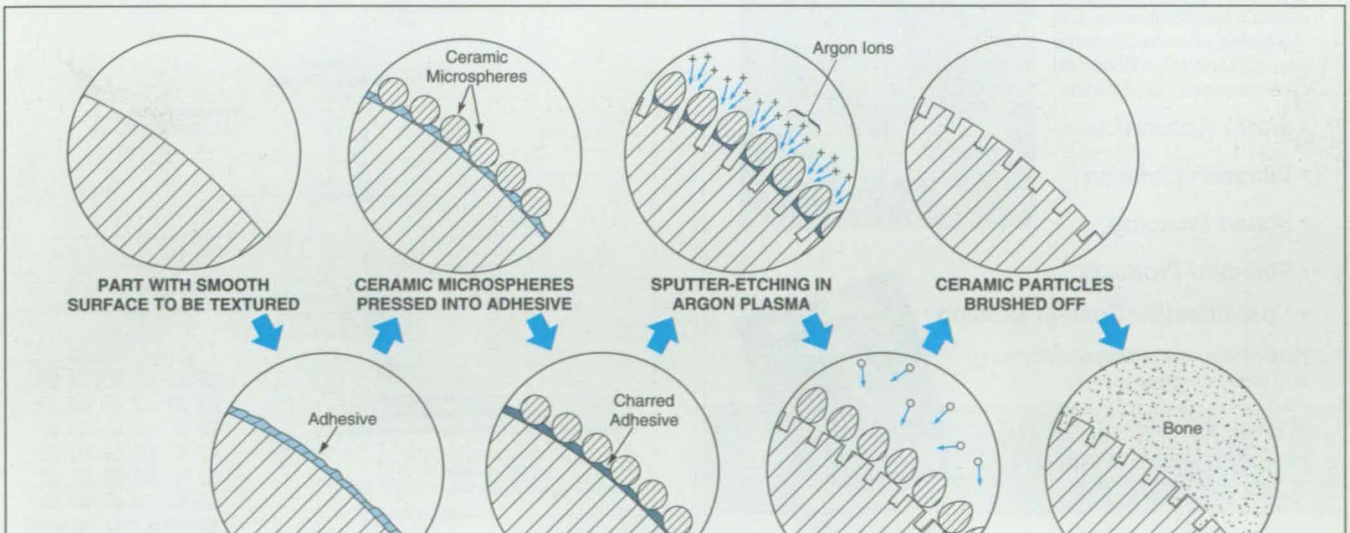
The process consists of the following steps (see figure):

1. By spraying or dipping, a film of contact adhesive is applied to the surface of the part to be textured.
2. Ceramic microspheres are pressed into the adhesive.
3. The part is heated in an oven to drive off volatile constituent compounds and char the adhesive.
4. The part is placed in the discharge chamber of an ion source or triode sputtering apparatus that operates with argon gas. The part is biased between –500 and –2,000 volts with respect to the plasma in its vicinity, causing argon ions to bombard the part and thus to sputter-etch the char and the underlying metal in the areas not covered by the ceramic microspheres. The depth of the etch is controlled by the voltage on the part, the duration of sputtering, and the ion-current density.
5. The part is placed in a radio-frequency plasma asher, where atomic oxygen removes the remaining charred adhesive.
6. The microspheres are brushed away.

Typically, in the case of a bone implant, the part to be textured is made of pure titanium or an alloy of 90 percent titanium, 6 percent aluminum, and 4 percent vanadium. A part to be textured for use in another application could be made of any of a variety of electrically conductive materials such as metals, carbon, and composites that contain metals and/or carbon. Mixtures of microspheres of different sizes can be used to obtain complex textures.

*This work was done by Bruce A. Banks of* **Lewis Research Center**. *For further information, **write in 61** on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Rd., Cleveland, Oh 44135. Refer to LEW-15823.*




**Texture Is Produced by Sputter Etching,** using temporarily bonded ceramic microspheres to mask areas not to be sputter-etched in an argon plasma. When etching is complete, the charred adhesive is removed to release the particles. A textured, bondable surface remains.

# Fiducial Grids for High-Resolution Beam Lithography

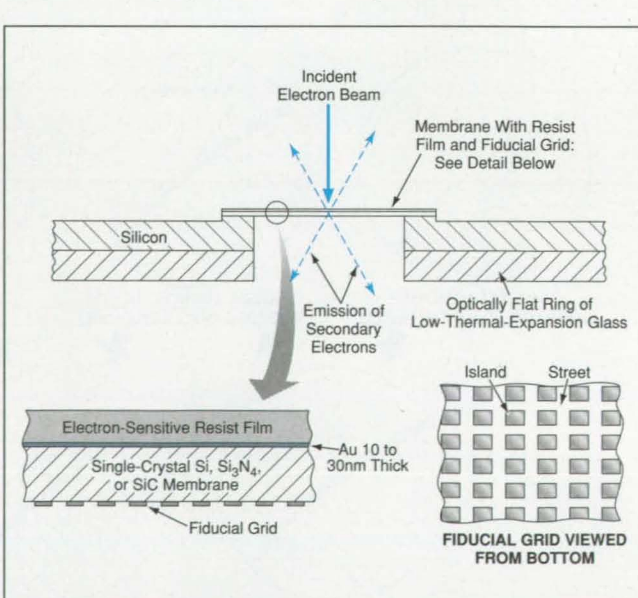
## The position of a beam can be determined to within a few nanometers.

*Marshall Space Flight Center, Alabama*

Fiducial rectangular grids are essential components in a method for making high-resolution masks with patterns accurate enough for use in x-ray lithography. High accuracy is necessary for achieving correct registration of multiple overlaid layers in integrated electronic circuits fabricated by use of such masks.

A mask of this type is made by electron-, ion-, or photon-beam lithography. Heretofore, it has been necessary to estimate the position $(x,y)$ of the beam in the two dimensions of the mask plane by use of the position readouts from a translation stage and/or any other device(s) used to scan the beam across the plane to form the pattern. Errors in the position estimates can arise from multiple sources, including thermal expansion, backlash and manufacturing tolerances in positioning mechanisms, misalignment between the substrate and scanning plane, nonorthogonality between the beam and substrate at some positions, and (in the case of an ion or electron beam) deflection of the beam by stray electric and magnetic fields. In the present method, one measures the position of the beam with the help of a fiducial grid; thus, it is no longer necessary to rely on possibly inaccurate beam-position estimates.

A fiducial grid of the type used in this method comprises metal-film islands separated by cross streets of comparable width and is either (1) formed on a surface or interior layer of, or else (2) mounted in a plane very close to, a multilayer membrane or a thicker substrate that one seeks to pattern into a mask by an electron-, photon-, or ion-beam lithographic process. A fiducial grid can be fabricated by holographic lithography; this technique is chosen because it




The **Position of Impingement of the Electron Beam** on the membrane can be identified as being on either an island or a street of the fiducial grid, as indicated by the level of emission of secondary electrons.

can be manipulated to obtain a set of cross gratings that are free of distortion or in which the distortion is exactly predictable. The gratings constitute a set of $(x,y)$ position references across the area to be patterned by the scanning beam.

The method can be practiced in many different versions, depending on specific applications. The figure illustrates an application that involves electron-beam lithography on a substrate with an electron-sensitive resist film on its top surface and a fiducial grid on its bottom surface. For measurement of position, the beam is attenuated so that it is not intense enough to produce appreciable changes in the electron-sensitive resist film yet is intense enough to cause emission of a measurable current of secondary electrons. This current can be measured by use of channel electron multipliers or other devices like those used to measure secondary electrons in scanning electron microscopes.

The secondary-electron yields of the islands and streets differ in a known way. Thus, at any instant as the beam is scanned across the grid, the level of the secondary-electron signal indicates whether the beam is impinging on an island or a street. If a raster scan is performed, then the secondary-electron readout can be processed, along with the scanning parameters and the scanning-apparatus readouts, by use of algorithms based on established techniques for analysis of moiré and interference fringes. These techniques make it possible to determine $(x,y)$ position to within a fraction of the spatial period of the fiducial grid. In a typical case, the spatial period would be 200 nm, and one could determine the position of the beam to within 20 nm or less.

*This work was done by Henry I. Smith, Erik H. Anderson, and Mark L. Schattenburgh of Massachusetts Institute of Technology for* **Marshall Space Flight Center**. *For further information, write in 56 on the TSP Request Card.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

*Massachusetts Institute of Technology*
*77 Massachusetts Avenue*
*Cambridge, MA 02139*

*Refer to MFS-26300, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# Software for Managing Multidimensional Data Files

**Users are relieved of much of the burden of translating between data formats.**

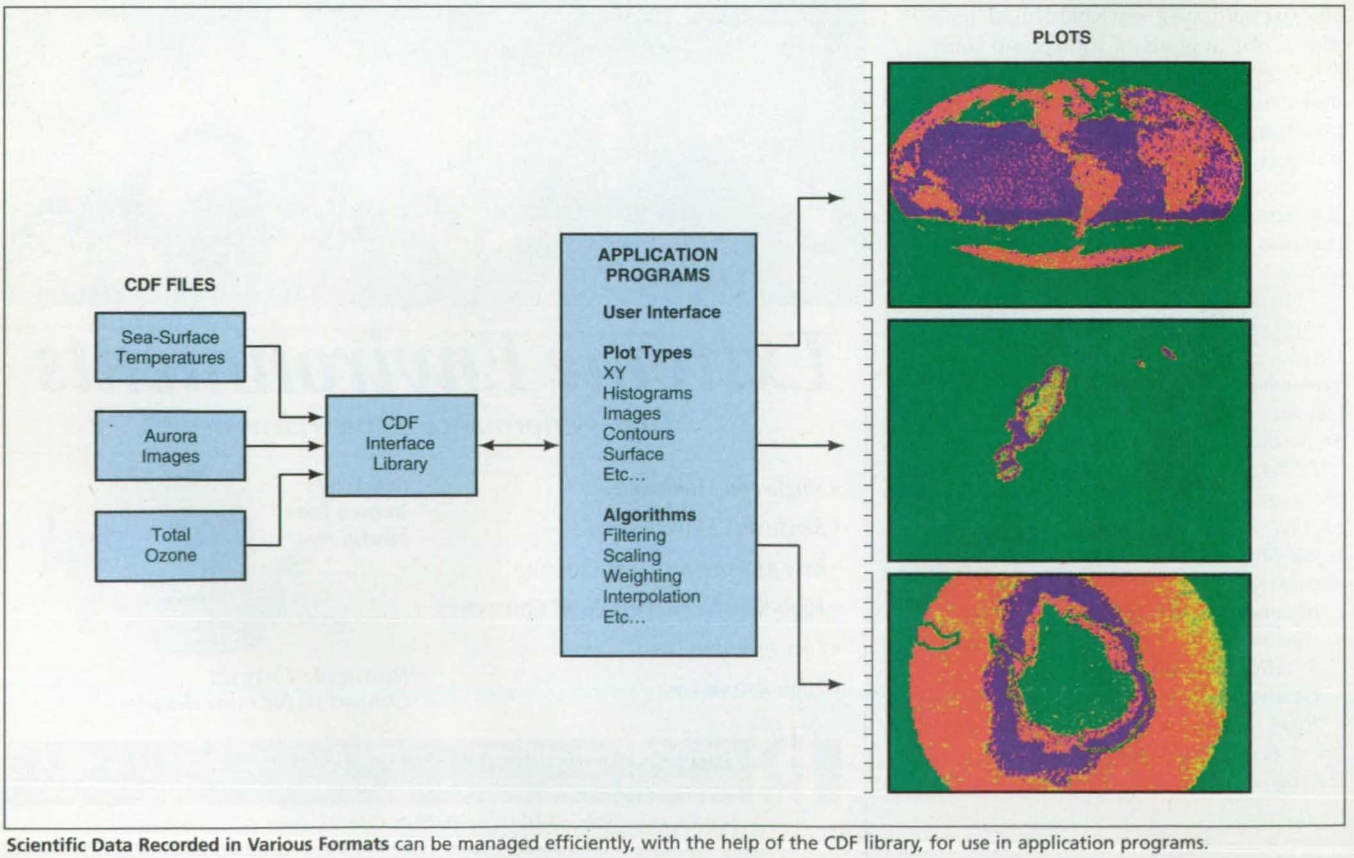
*Goddard Space Flight Center, Greenbelt, Maryland*

The Common Data Format (CDF) Library is a portable software package for managing collections of scientific data that were originally recorded on magnetic tapes and other media in a variety of hardware- and software-based formats. Developed at the National Space Science Data Center at NASA's Goddard Space Flight Center for use in storing and distributing data, this software has also been distributed internationally and adopted by thousands of users that include government agencies, universities, commercial organizations, and independent researchers.

The CDF Library can save much time in the storage and retrieval of scientific data, minimizing the need for users to translate between different data and encoding formats. The hallmark of the CDF library is independence of data-management functions from specific sets of data. This independence is achieved by means of an internal format that is transparent to the programmer and is accessible through an easy-to-use standard set of interface routines in FORTRAN- and C-language versions. In a given application, the internal format includes a data dictionary (metadata) supplied by the user, plus the data themselves. Thus, in effect, the CDF describes itself; this self-describing property is what makes the CDF useful for managing data that originate in various formats from various scientific disciplines.

By itself, the concept of using an internal data dictionary to describe the contents of a data file and thereby achieve a data-independent, transportable standard format is not new. The unique contribution made by the CDF Library to go beyond modern business-oriented commercial relational data-management software to support multidimensional, hierarchical data structures, enabling programmers to manage multidimensional data in ways consistent with the geometries of their own scientific organizations. The CDF Library also serves as a software framework that facilitates the creation of generic application programs for typical data-management and data-abstraction functions like visualization, statistical analysis, and browsing. The CDF Library enables programmers to easily create application programs that enable users to slice data across multidimensional subspaces, gain access to entire structures of data, perform subsampling of data, and gain access to one element regardless of its relationship to any other element (see figure).

Both the metadata and the data are accessible via the interface routines, which afford the programmer an abstract view of the contents of the CDF. The programmer need not know the details of




**Scientific Data Recorded in Various Formats** can be managed efficiently, with the help of the CDF library, for use in application programs.

(and is isolated from) the CDF physical storage and the underlying software structure. The programmer does not have to perform low-level input/output functions to physically pack or unpack data or metadata into or out of files; the CDF software does this for the programmer. The physical files (CDF files) generated by the CDF Library can be retrieved directly or sequentially and can be stored on disks for access via a FORTRAN or C interface. The isolation of the programmer and user from the physical storage and the underlying software structure also make it possible to enhance the implementation of the CDF as new hardware and software become available.

*This work was done by Gregory Gauchers, Jason Mathews, Jeff Love, and Howard Leckners of* **Goddard Space Flight Center**. *For further information,* ***write in 70*** *on the TSP Request Card. GSC-13633*

# Algorithm for Improving a Mathematical Model

### Linear least-squares solutions with optimal step sizes are iterated.

*Marshall Space Flight Center, Alabama*

The Analytical Model Improvement (AMI) computer program implements an iterative algorithm for improving a mathematical model of a physical system. The algorithm adjusts the parameters in the model to obtain a closer match between data on the behavior of the system as calculated by the model and the corresponding data obtained by experiment. The original application for which AMI was developed involves a vibrating structure represented by a finite-element model, the data of interest being the shapes (eigenvectors) and natural frequencies (eigenvalues) of the vibrational modes and the parameters of interest being the design parameters of the structure.

AMI was developed with recognition that in a general case, both the experimental data and the mathematical model can contain errors. AMI seeks a least-squares best fit between the model and experimental data. The process begins with calculation of an error vector, $\Delta$, the elements of which consist of differences between the experimental

and model data. Typically, these data are the eigenvalues and the components of the eigenvectors. At first, it is assumed that the following linear approximation applies:

$$\Delta = \mathbf{J}\delta,$$

where $\delta$ is a vector of design-parameter changes needed to bring the experimental and model data into agreement and $\mathbf{J}$ is the Jacobian matrix that contains partial derivatives of the model eigenquantities with respect to the design parameters. Singular-value decomposition is used to find a search direction in parameter space, which is identical to the linear least-squares solution $\delta$.

Because significant nonlinearities are often present, the linear least-squares solution can diverge from the true solution, making it necessary to solve the model-improvement problem iteratively, as a sequence of linear least-squares problems. On each iteration, one must find a fraction, $\alpha$, of the linear least-squares solution that yields an optimal match between the experimental and model data; in other words, on each iteration, the problem becomes one of finding a $(0 \leq \alpha \leq 1)$ such that $\hat{\delta} = \alpha\delta$ yields a minimum value of an error measure (called the "residual") given by $r = |\Delta|_2$.

AMI implements two alternative methods for approximating the eigenquantities and finding a value of $\alpha$ that minimizes $r$. One method involves the use of a variation of the method of moving asymptotes; the other method involves the use of a generalized quadratic equation. In both methods, second-order approximations of the eigenquantities are obtained by use of first and second partial derivatives of the eigenquantities with respect to the design parameters. The first derivatives are determined by a finite-difference technique. After the first update cycle, the first derivatives can then be compared to the first derivatives from the previous cycle to estimate the primary second derivatives, also via a finite-difference technique. However, when a second derivative $\leq 0$, a small positive number is substituted; this provides a so-called convex approximation, which yields a unique solution.

The second-order approximations of the eigenquantities provide an estimate of $r$ that depends only on $\alpha$; that is,

$$r(\alpha) = |\Delta(\alpha)|_2$$

A one-dimensional line-search optimization routine in the International Math and Statistics Library (IMSL) computer program is used to find the value of $\alpha$ that minimizes $r(\alpha)$. Then $\alpha$ is used to update the design variables via $\hat{\delta} = \alpha\delta$. This completes the computational cycle. Then using the updated design variables, a new cycle can be started. The iteration is stopped when sequential vectors of design variables converge.

*This work was done by Matthew F. Orr, Jr., of* **Marshall Space Flight Center**. *For further information,* ***write in 21*** *on the TSP Request Card. MFS-31179*

# Collar Grids for Computing Flows at Intersections

## Collar grids resolve the interaction regions and provide communication between component grids.

*Ames Research Center, Moffett Field, California*

Collar grids are placed at intersections of surfaces in an improved version of the chimera overlapping-grid scheme that is used in computing flow fields about aircraft and other complicated bodies. In the chimera scheme, multiple overlapping component grids that conform to the surfaces of

wings, fuselages, and other components are used to solve the Navier-Stokes or Euler equations of flow by numerical integration. Information on the flow fields at the boundaries between grids is communicated between component grids by interpolation. However, for computations of viscous flows in the vicinities of intersections between surfaces (e.g., wing/fuselage intersections), the generation of suitable grids and the mathematical analogs of stencils to be used in interpolations in the intersection regions is not straightforward. Problems arise in connection with such matters as the resolution of the intersection regions and the appropriate definitions of the surfaces. The collar grids were devised as solutions of these problems.

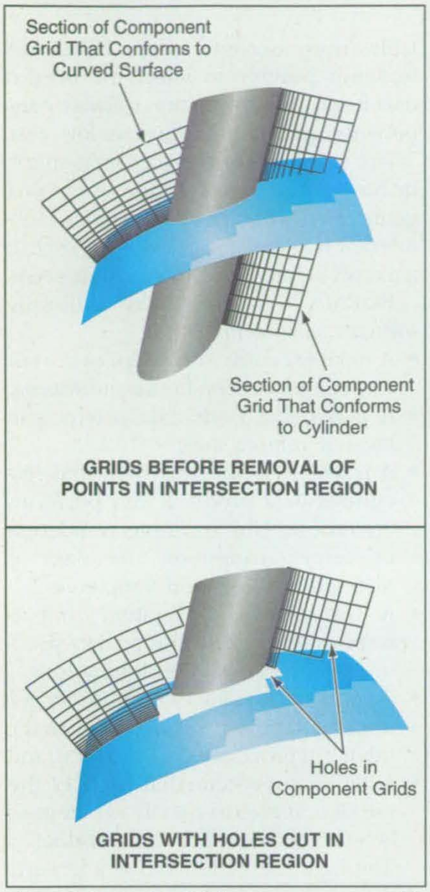



Figure 1. **Holes Are Cut** in the component grids at the intersection of a cylinder and a curved surface.

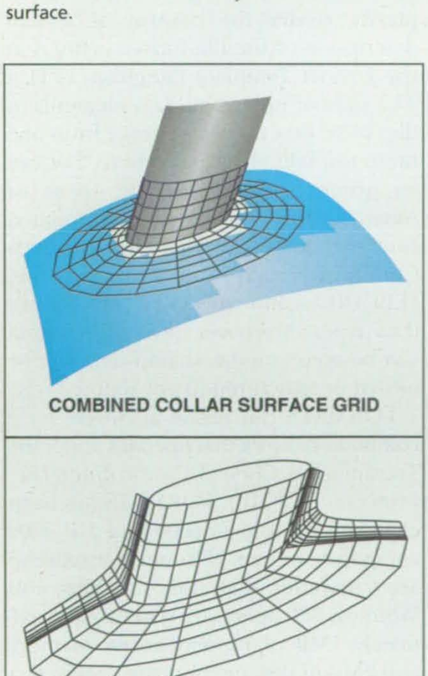



Figure 2. The **Collar Grid** is placed in the holes, filling the intersection region.

In a representative application of the chimera scheme to an intersection between a cylinder and a curved surface, holes are cut in the two component grids in the intersection region (see Figure 1). In computation, holes are implemented by deleting the points in the holes from the domain; that is, by setting the contributions of those points to changes in the flow field equal to zero. Those points of each component grid that lie on the boundary of its hole are the points that receive flow-field data interpolated from the other component grid.

In the improved version of the chimera scheme, the overall hole formed by superposition of the two holes is filled with the collar grid (see Figure 2). The collar grid provides the communication between the component grids and spatially resolves the computed flow field in the intersection region. To avoid problems that might otherwise arise in geometric conflicts between the fine grid needed to resolve viscous flow in the intersection region and a typical component surface grid, the edges of the collar surface grid are generated by trilinear interpolation of the component surface grids. Component-grid points on the boundaries of the holes are moved to the surfaces defined by the collar grids. Once the collar and component grids are thus configured, interpolation stencils generated by the grid-joining software correctly reflect the relative locations of the component and collar grids. No other modifications of the chimera scheme and no modifications of the flow-computing algorithm are needed.

*This work was done by Pieter Buning of* **Ames Research Center**, *Steven J. Parks of Lockheed Engineering & Sciences Co., William Chan of MCAT Institute, and Joseph Steger of the University of California, Davis. For further information,* ***write in 67*** *on the TSP Request Card.*
*ARC-13183*

## Software for Transforming Data Formats

**This program features a menu- and table-driven user interface.**

*Goddard Space Flight Center, Greenbelt, Maryland*

The Flight Dynamics Orbital and Mission Aids Transformation System (FORMATS) computer program collects data in the formats in which they are generated and distributes them in the same formats or any of a wide variety of different formats, as specified by users. FORMATS was developed for use in reformatting and distributing data generated during scientific spacecraft missions, but its adaptability to multiple formats may also be useful in terrestrial applications; for example, transforming data generated by laboratory instruments.

Because FORMATS incorporates selectable software components needed to transform data among many different formats, expensive reprogramming is not necessary to satisfy requirements for each new data-distribution task. A menu- and table-driven user interface in FORMATS makes it possible to select the needed data-format-transformation software components quickly and thus at low cost. There is minimal need for intervention by the user during execution of the program. The program also includes fault-tolerant features; for example, it repeats attempts to transmit data until it succeeds.

FORMATS includes the following software subsystems:

- A small executive subsystem to start or stop the execution of other subsystems;
- A poller that finds data products in local or remote sites;
- A transformation subsystem that recognizes data products and performs operations (for example, validation or reformatting) on the data as directed by tables and templates;
- A transmission subsystem that is responsible for distributing data products to their respective destinations;
- An optional user-interface subsystem for displaying messages associated with the validity of processed data products; and
- A tables subsystem that enables the use of text files to specify the steps to be executed for each data product.

The heart of FORMATS is a generic data-transformation engine that can navigate any data file, regardless of its complexity, under the control of textual description of the file format, written in the Format Template Language (FTL). The sizes of individual data elements in files to be processed can range from one bit to two billion bytes. Formats that can be accommodated include those of American Standard Code for Information Interchange (ASCII), Extended Binary-Coded Decimal Interchange Code (EBCDIC), and special floating-point data types. Moreover, any time format can be accommodated, and data can be nested or structured in any defined way.

FORMATS can reside anywhere on a computer network that operates under the Transmission Control Protocol/Internet Protocol (TCP/IP). FORMATS has been executed on IBM RS6000 and HP 9000 computers under UNIX and is portable to any computer that uses the Microsoft Windows NT operating system. Approximately 1MB of random-access memory and 2MB of disk memory are required.

*This work was done by Alan T. Johns, Douglas B. Reingold, and George E. Coon of CSC Communications Industry Services for* **Goddard Space Flight Center**. *For further information, write in 66 on the TSP Request Card. GSC-13827*

# Life Sciences

## Instrument Measures Populations of Microbes in Water

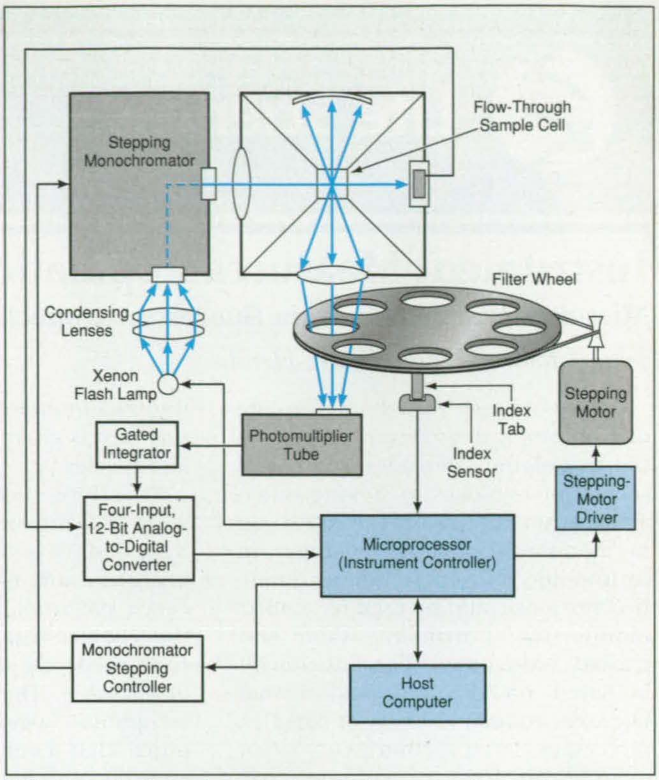
**Microbes are identified via fluorescence spectra.**

*John F. Kennedy Space Center, Florida*

An instrument called an "on-line microbiological analyzer" measures the population densities of several species of microbes in flowing water. The instrument was conceived for use in monitoring harmful microbes in hydroponic nutrient solutions; modified versions could be used for similar monitoring of drinking water and treated waste-water. The instrument is based on the observation that microbes contain a variety of complex molecules that fluoresce when exposed to light of certain wavelengths; tryptophan, for example, emits light at a wavelength of 348 nm when it is stimulated by light at 287 nm. A microbe fluoresces in a spectrum that depends on the mix of fluorescent molecules that it contains; this mix is characteristic of its genus and species.

Therefore, the instrument illuminates flowing water with ultraviolet light to excite fluorescence in microbes and measures the fluorescence spectrum, which can comprise the characteristic fluorescence spectrum or spectra of one or more species of microbes. Then, by use of pattern-recognition algorithms, a host computer that controls the instrument analyzes the measured spectrum to identify and quantify the single characteristic spectrum or multiple component characteristic spectra, thereby estimating the population density or densities of the species present.

The instrument is illustrated schematically in the figure. A xenon flash lamp generates pulses of broad-spectrum light that pass through a monochromator and into a cell, through which flows the water to be monitored. The monochromator includes a plane grating and a moving mirror that operate under stepping control to obtain a sequence of beams of light in different narrow-wavelength bands at the excitation wavelengths of interest. The beam selected at any given instant enters the flowing water through a slit in the cell. Fluorescence emitted by the microbes in a direction perpendicular to the incident beam of light is band-pass filtered at a fluorescence wavelength of interest and measured




**Light From the Monochromator Excites Fluorescence** in microbes in water flowing through the cell. The photomultiplier converts filtered fluorescent emissions to signals for processing and analysis. The microprocessor coordinates the operations of the monochromator, the filter wheel, and the circuitry that process the output of the photomultiplier.

by use of a photomultiplier. The cell contains a photodiode that measures the intensity of the illumination so that the fluorescence signals can be normalized.

Band-pass filters for the fluorescence wavelengths of interest are mounted on a wheel, which is rotated to place the filter for the desired fluorescence wavelength in front of the photomultiplier. The photomultiplier output is integrated over a series of flashes, then passed to an analog-to-digital converter. A microprocessor selects the monochromator and filter-wheel settings for the excitation and fluorescence wavelengths required in a given measurement, coordinates the operation of the flash lamp with acquisition of data, and communicates with the host computer.

The digitized fluorescence-signal data for all the wavelengths of interest are sent to the host computer for processing by the pattern-recognition algorithms. Of the algorithms tested thus far, one performs a rotated-principal-components regression analysis; it has been found to be suitable for determining total population densities and identifying genera, but does not do as well at identifying species. Another algorithm performs a genetic-neural-network analysis and has been found to perform well at the species level.

*This work was done by Kenneth J. Schlager of Biotronics Technologies, Inc., for* **Kennedy Space Center**. *For further information,* ***write in 53*** *on the TSP Request Card.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

*Kenneth J. Schlager*
*Biotronics Technologies, Inc.*
*W226 N555B Eastmound Dr.*
*Waukesha, WI 53186*

*Refer to KSC-11755, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# Books & Reports

### Analysis of the Defect Structure of B2 FeAl Alloys

A report presents a study of the defect structure of the B2 phase of FeAl alloys. In the study, the BFS method was used to analyze the defect structure of FeAl from the perspective of energy considerations at zero absolute temperature. The BFS method is based on the idea that the energy of formation of an alloy can be calculated as a superposition of contributions from individual nonequivalent atoms in the alloy. BFS calculations were performed on a large number of candidate ordered structures to determine the configurations of lowest energy and to search for states that could be metastable. Overall, the results of the calculation were found to provide a description of the defect structure consistent with available experimental data: For example, the calculations were successful in determining the phase field of the B2 structure; the results were consistent with experimental observations that the B2 phase is stable at aluminum contents up to about 52 atomic percent. The results were also in qualitative agreement with experimental observations that the lattice parameter increases with aluminum content.

*This work was done by John Ferrante and Ronald D. Noebe of* **Lewis Research Center**, *Guillermo Bozzolo of Analex Corp., and Carlos Amador of Universidad National Autónoma de México. To obtain a copy of the report, "Analysis of the Defect Structure of B2 FeAl Alloys,"* ***write in 76*** *on the TSP Request Card.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16426.*

### VPS Fabrication of Parts To Withstand High Temperatures

A short paper reviews the state of the art of making refractory-metal and ceramic/refractory-metal composite objects by vacuum plasma spraying (VPS) of the constituent materials onto graphite mandrels. In large part, the paper reiterates descriptions of selected aspects of VPS fabrication technology of high-temperature parts as reported in prior articles in *NASA Tech Briefs*.

*This work was done by Philip D. Krotz of Rockwell International Corp. and William M. Davis of Boeing North American, Inc., for* **Marshall Space Flight Center**. *To obtain a copy of the paper, "Vacuum Plasma Spray Fabrication of Solar Thermal Rocket Engines,"* ***write in 55*** *on the TSP Request Card.*

*MFS-30104*

*continued from page 23*

## National Design Engineering Show New Product Showcase

Colder Products, St. Paul, MN, offers Sixtube™ **multiple-line couplings** that connect up to six fluid or pneumatic lines simultaneously. They feature thumb-latch connection and snap-in panel mount, as well as flow paths made of acetal or polypropylene materials. They connect 1/16" or 1/8" ID tube sizes. Applications include fluid management and pneumatic control systems, factory automation, machine tools, biomedical instrumentation, and testing equipment.

**For More Information Write In No. 777**


DuPont Specialty Chemicals, Deepwater, NJ, offers KryTech paraffin wax all-purpose **lubricant** that protects against dirt, grime, and water. The lubricant is formulated with Krytox® fluoropolymer and 10 other ingredients, including paraffin waxes and synthetic oils. The lubricant is applied wet to chains, cables, lock mechanisms, and hinges. As it sets, it forms a hard, dry wax film that repels dirt, grit, grime, and water. Although the wax film sheds with normal wear, the Krytox remains and bonds to metal friction surfaces. The lubricant provides high-temperature resistance, nonflammability, and nonreactivity to chemicals in bearings, gaskets, seals, and other parts.

**For More Information Write In No. 779**

Aromat Corporation, New Providence, NJ, has introduced the FPO pocket-sized **programmable logic controller** (PLC) that is available in 10, 14, 16, and 32 I/O base units, with relay or transistor outputs. Relay units have removable terminal strips; transistors have connectors. The PLC expands to 128 I/O with maximum volume of 3-1/2 × 4-1/8 × 2-3/8". Simultaneous dual-axis motion control with up to 10 KHz pulse output provides high-speed control of stepper or servo motors. Features include four-function math, an optional second RS-232C port, four high-speed inputs, run-time edit for "on-the-fly" program changes, and Fpsoft™ Windows programming software.

**For More Information Write In No. 780**

MSC/InCheck **CAD simulation software** from MacNeal-Schwendler Corp., Los Angeles, CA, provides mechanical simulation capabilities to users of Autodesk Mechanical Desktop CAD/solid modeling system in a Windows interface. A Simulation Wizard guides users step-by-step through the simulation process. The software uses the 3D solid model in Mechanical Desktop as a basis for its simulation model. Materials, environmental loads, and boundary conditions and simulation results are processed within Mechanical Desktop.

**For More Information Write In No. 764**

The SG3 and SG4 right-angle **gearheads** from Bodine Electric, Chicago, IL, mate to existing AC, DC, and brushless motors and run for more than 20,000 hours continuously. Both models have a wide, single, enveloping worm gear to permit an increase in load capacity and longer life. The SG3 is available with six ratios and an output torque capacity of 97 in-lbs. The SG4 comes with five ratios and an output capacity of 168 in-lbs. The enclosed gearheads feature Viton, double lip, bidirectional helix seals on the input and output shafts, as well as permanently lubricated gear housing. Four mounting surfaces are offered and a single-, double-, or hollow-drive shaft is available.

**For More Information Write In No. 766**

Eastern Air Devices, Dover, NH, offers **linear actuator motors** that work with a variety of ball screw assemblies. Motors are available as complete assemblies or the hub can be built to accommodate user-installed ball screw housings. The motor design allows for a shaft to travel completely through the center of the motor. Available in three frame sizes, the motors accommodate varying ball screw diameters. The size 23 (2.25" diameter) motor accommodates up to a 5/16" ball screw; the size 34 (3.38") up to a 3/8" screw; and the size 42, up to a 5/8" screw. They offer voltage ratings from 1.4 to 24 VDC.

**For More Information Write In No. 767**

## New on the Market

The CN530 Series microprocessor-based, programmable **temperature controller and timer** from OMEGA Engineering, Stamford, CT, is used on batch-type equipment requiring accurate time and temperature cycles. Digital displays combine temperature and timer functions into a single 1/4 DIN-size enclosure. Units with one, two, or three outputs and with RTD or thermocouple input are available.

**For More Information Write In No. 723**

Planar Systems, Beaverton, OR, has announced the ColorBrite™ family of full-color, **active matrix liquid crystal displays** in standard sizes ranging from a 5.5" (diagonal) 1/4 VGA product to a 12.1" XGA. The displays feature enhanced brightness and viewing angle for better readability in sunlight.

**For More Information Write In No. 720**

Ruska Instrument Corp., Houston, TX, has introduced the Model 7310 high-pressure **pneumatic controller** for automation of high-pressure pneumatic calibration and testing of instruments. It provides 0.01% accuracy and features menu-driven displays, built-in programming functions, and remote interfaces for PC-based automation. Full scale ranges are available for 3000, 6000, and 10,000 psi.

**For More Information Write In No. 725**

Global Servo Drives, Div. of Lenze, Montvale, NJ, offers the 9300 Series digital **AC servo drive** for positioning and field bus interfaces. The self-contained single- or multi-axis drives use a Windows-based user interface for setup and programming. CAN field-bus is standard, with Interbus-S, Profibus, fiber optic, and RS232/482 available as options.

**For More Information Write In No. 722**

Servometer Corp., Cedar Grove, NJ, offers flexible **bellows** for EMI/RFI shielding. Used in weight-critical applications such as satellites and aircraft, they are available in diameters from 0.125" to 7" and can be electroformed from nickel, copper, gold, or silver.

**For More Information Write In No. 726**

The QTERM-K60 **graphical operator interface/data terminal** from QSI Corp., Salt Lake City, UT, features a 240 x 128 lighted graphics LCD and wide-temperature operation. Other features include communications to 38,400 baud and 12 lighted soft keys. It is available in panel or pedestal mount versions and includes Visual Terminal Protocol™ (VTP) programming software.

**For More Information Write In No. 724**

Vexta® bidirectional low-speed synchronous **AC motors** from Oriental Motor U.S.A. Corp., Torrance, CA, operate at standard voltage levels with input voltages of 24 vac, 100 vac, 115 vac, 200 vac, or 230 vac. The dual-frequency motors deliver from 18 to 297 oz-in rate torque at a constant speed of 72 rpm.

**For More Information Write In No. 721**

The SLA SmartStart™ **rapid prototyping system** from 3D Systems Corp., Valencia, CA, fabricates three-dimensional physical objects using input from CAD/CAM systems. Included are the SLA-250/30A, Maestro/JR software for Silicon Graphics and Hewlett Packard platforms, and Cibatool® SL 5170 epoxy resin. The system features a 10" cube build envelope that accommodates a range of part sizes.

**For More Information Write In No. 727**

 **For More Information Write In No. 434** 

# New Literature


Magnet Sales & Manufacturing, Culver City, CA, offers a 64-page catalog of high-performance permanent **magnets.** Neodymium iron boron, samarium cobalt, ceramic, alnico, and flexible magnets are available in a variety of standard and custom assemblies and finishes.

**For More Information Write In No. 702**


Techni-Tool, Plymouth Meeting, PA, has released a 264-page catalog of **tools, tool kits, and test equipment,** as well as production aids and computer accessories. Included are electro-mechanical and assembly devices, electronic and telecommunication tools, production tools, custom and field service tool kits, and static control items.

**For More Information Write In No. 705**


**Power supplies** for process controls, CNC machinery, and instrumentation are described in a 20-page brochure from Sola/Hevi-Duty, Goldsboro, NC. Included are switchers, single- and multi-output linears, linears for MRO applications, and encapsulated linears.

**For More Information Write In No. 703**

Delta Computer Systems, Vancouver, WA, offers literature describing the MC 186/40 **motion control module** for hydraulic setworks systems. The module moves equipment or materials to virtually any linear position and features positive control and protection through optically isolated inputs and outputs.

**For More Information Write In No. 701**

Network Technologies, Aurora, OH, offers a brochure describing **dual-platform switches** that enable one user to access two computers operating on PC, Sun, or Mac platforms. The switches allow instant switched access between PC file servers and Sun Internet servers operating on different platforms.

**For More Information Write In No. 704**


A 32-page catalog from Zippertubing, Los Angeles, CA, describes **zip-on jacketing and shielding systems.** Featured are wraparound re-enterable jacketing products, EMI shielding, custom designs, tapes, tools, and accessories.

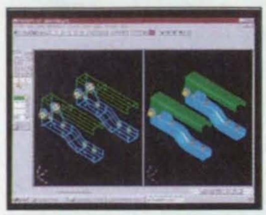
**For More Information Write In No. 707**

The 48-page Catalog M-97 from Velmex, East Bloomfield, NY, features motor-driven **positioning and scanning slide assemblies.** Linear and rotary assemblies for single- or multi-axis systems are available in eight cross section sizes from 1.5" to 9" and travel from 0.5" to 86."

**For More Information Write In No. 700**

# New on Disk

## Product of the Month



Baystate Technologies, Marlborough, MA, has announced CADKEY® 97 **mechanical CAD software** for Windows 95, NT 3.51, and 4.0. The program combines wireframe modeling with ACIS® solid modeling, allowing import or export of 2D/3D data to other CAD/CAE/CAM applications supporting the ACIS solid model kernel; converting wireframe to a solid model; construction of solids such as blocks, cones, and cylinders; rotation of shaded models; Boolean operations; application of constant and variable fillets; and extruding, sweep, or revolving geometry into a solid. Other enhancements include an optional DOS-type interface, improved rendering, and macro support. The cost is $1,195.

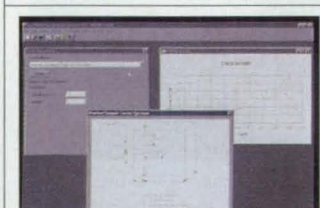
**For More Information Write In No. 713**

PV-WAVE: Image Processing Toolkit from Visual Numerics, Boulder, CO, is an **image analysis and manipulation software** program that provides the ability to manipulate and analyze image data and distribute the results over the Internet or intranets. The software is compatible with Windows 95/NT, Linux, and UNIX systems, and features six predefined tools for imaging, histograms, contouring, surfacing, plotting, and color manipulation. Prices are $1,295 for Windows and Linux, and $2,495 for UNIX.

**For More Information Write In No. 717**

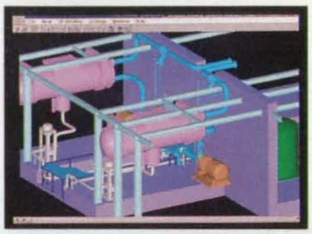
EXP: The Scientific Word Processor, Version 5.0 **scientific word processing software** for Windows 95 and NT from Brooks/Cole Publishing, Pacific Grove, CA, mixes mathematics and scientific notation with text and graphics, allowing the user to see all text, mathematics, graphics, and formatting displayed on the screen as they will print. It contains more than 500 technical symbols, as well as multiple fonts, style sheets, and tables.

**For More Information Write In No. 711**



Structural Integrity Associates, San Jose, CA, has introduced a Windows version of pc-CRACK™ **fracture mechanics software**, which displays fracture mechanics results. The program incorporates 25 fracture mechanics models for a variety of crack/structure configurations. Fatigue and stress corrosion crack growth capability also is provided, as well as built-in material properties for selected materials. Three modules are available: Linear-Elastic Fracture Mechanics; Elastic-Plastic Fracture Mechanics; and ASME Codes and Standards.

**For More Information Write In No. 716**



The AEC Guardian™ **3D model translation software** from CAD/CAM Support Alliance, West Hills, CA, enables mainframe CADAM® customers to migrate AEC engineering designs to PCs. The program provides a Windows NT native environment that uses OPENGL enablers for 3D solids model viewing, translation, drawing generation, and reporting. It supports Microsoft OLE standards and consists of four modules: AG Host Manager, AG Designer, AG Drafter, and AG Viewer. The Viewer allows display of designs independent of AEC Guardian.

**For More Information Write In No. 712**

Structural Dynamics Research Corp., Milford, OH, has introduced the I-DEAS Artisan Series™ **solids-based mechanical design software** for Windows NT that enables solid modeling, assembly design, drafting/documentation, and mechanism analysis for production environments. Users can design production products using 3D solid models and migrate CAD data to a concurrent engineering environment.

**For More Information Write In No. 714**

Analytical Graphics, King of Prussia, PA, offers Visualization Option for Satellite Tool Kit® **3D analysis software** for Pentium®-class PCs. The program allows users to view realistic object animations and make decisions based on data displayed numerically and graphically. Providing 3D satellite analysis, the software module can be purchased alone, or as part of a bundled package with a graphics card on a Pentium PC.

**For More Information Write In No. 710**

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